Radiation Data and Reports

VOLUME 14, NUMBER 4

APRIL 1973

(Pages 225–272)

RDDRA4 14(4) 225–272 (1973)

U.S. ENVIRONMENTAL PROTECTION AGENCY

Office of Radiation Programs

INTERNATIONAL NUMERICAL MULTIPLE AND SUBMULTIPLE PREFIXES

Multiples and submultiples	Prefixes	Symbols	Pronunciations
10^{12}	tera	T	tĕr'a
10^{9}	giga	G	jĭ'ga
10^{6}	mega	M	mĕg'a
10^{3}	kilo	k	kĭ'lo
10^{2}	hecto	h	hĕk'to
10	deka	da	dĕk'a
10^{-1}	deci	d	dĕs'i
10^{-2}	centi	c	sĕn'ti
10^{-3}	milli	m	mĭl'i
10^{-6}	micro	μ	mi'kro
10^{-9}	nano	n	năn'o
10^{-12}	pico	p	pē'ko
10^{-15}	femto	f	fĕm'to
10^{-18}	atto	a	ăt'to

SYMBOLS, UNITS, AND EQUIVALENTS

Symbol	Unit	Equivalent
Å	angstrom	10^{-10} meter
A	ampere(s)	
a	annum, year	
BeV	billion electron volts	GeV
Ci	curie	3.7×10^{10} dps 2.22×10^{12} dpm
cpm	counts per minute	
dpm	disintegrations per minute	
dps	disintegrations per second	
eV	electron volt	1.6×10^{-12} ergs
g	gram(s)	3.527×10^{-2} ounces$_M$ 2.205×10^{-3} pounds
Hz	hertz	cycle per second
kVp	kilovolt peak	
m	meter(s)	39.4 inches
m^3	cubic meter(s)	
mCi/mi^2	millicuries per square mile	0.386 nCi/m^2 (mCi/km^2)
mg	milligram(s)	
mi	mile(s)	
ml	milliliter(s)	
nCi/m^2	nanocuries per square meter	2.59 mCi/mi^2
R	roentgen	
rad	unit of absorbed radiation dose	100 ergs/g
s	second	

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RADIATION DATA AND REPORTS

Volume 14, Number 4, April 1973

Radiation Data and Reports, a monthly publication of the Environmental Protection Agency, presents data and reports provided by Federal, State, and foreign governmental agencies, and other cooperating organizations. Pertinent original data and interpretive manuscripts are invited from investigators.

In August 1959, the President directed the Secretary of Health, Education, and Welfare to intensify Departmental activities in the field of radiological health. The Department was assigned responsibility within the Executive Branch for the collation, analysis, and interpretation of data on environmental radiation levels. This responsibility was delegated to the Bureau of Radiological Health, Public Health Service. Pursuant to the Reorganization Plan No. 3 of 1970, effective December 2, 1970, this responsibility was transferred to the Radiation Office of the Environmental Protection Agency which was established by this reorganization.

The Federal agencies listed below appoint their representatives to a Board of Editorial Advisors. Members of the Board advise on general publications policy; secure appropriate data and manuscripts from their agencies; and review those contents which relate to the special functions of their agencies.

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Environmental Protection Agency
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U.S. ENVIRONMENTAL PROTECTION AGENCY

William D. Ruckelshaus, Administrator

Radiobioassay Program of the Institutional Total Diet Sampling Network II. Selected Physiological Constants of Urine

A. A. Moghissi and Mary G. Mayes [1]

The Institutional Total Diet Sampling Network program, initiated in 1961, has provided information on the intake of certain radionuclides by selected groups of children and young adults, and the resulting radiation dose. Starting with 1966, this was supplemented by a radiobioassay program with the aim of improving radiation dose estimates by using excretion data. Numerous physiological parameters were measured to evaluate their suitability for the validation of a 24-hour urine sample.

The results of measurements of volume, specific gravity, pH value, osmolality, and creatinine in samples collected during 1966–1968 are summarized. Results of these measurements, along with a review of available data, with particular emphasis on creatinine, are presented and discussed.

The Institutional Total Diet Sampling Network program (ITDSN) is described in an earlier report (*1*). In initiating a radiobioassay program in 1966, 10 of the stations (figure 1) were selected for special sampling and determination of urinary constants. The analytical data for this program have been reported (*2*).

By examining the data from urine samples in correlation with food intake values, a better evaluation of the possible radiation hazard was anticipated. A brief description of the radiobioassay program of the ITDSN, and preliminary findings related to cesium-137 (*3*) and tritium (*4*), were previously reported.

Our investigations of the physiological constants will be described below. For convenience, the description of physiological constants reported by other authors will be discussed as well, under the headings for the specific constants.

Procedures and methods

The details of the sample collection and analytical procedures were reported previously (*3*). These have been modified slightly during the course of operation of the program.

The volume, specific gravity, and pH of the samples were determined by conventional techniques. Osmolality was determined by means of an osmometer manufactured by Advanced Instrument, Inc.[2] The standard provided by the manufacturer consisted of a sodium chloride solution containing colloids, to simulate biological specimens.

Creatinine was analyzed by the Folin (*5*) technique as modified by Clark and Thompson (*6*). Various substances, including certain drugs, glucose, acetone, and acetoacetic acid, may affect the accuracy of the analysis (*6–8*).

[1] National Environmental Research Center—Las Vegas, Environmental Protection Agency, Las Vegas, Nev.

[2] The use of the names of proprietary firms or products does not imply endorsement by the Environmental Protection Agency.

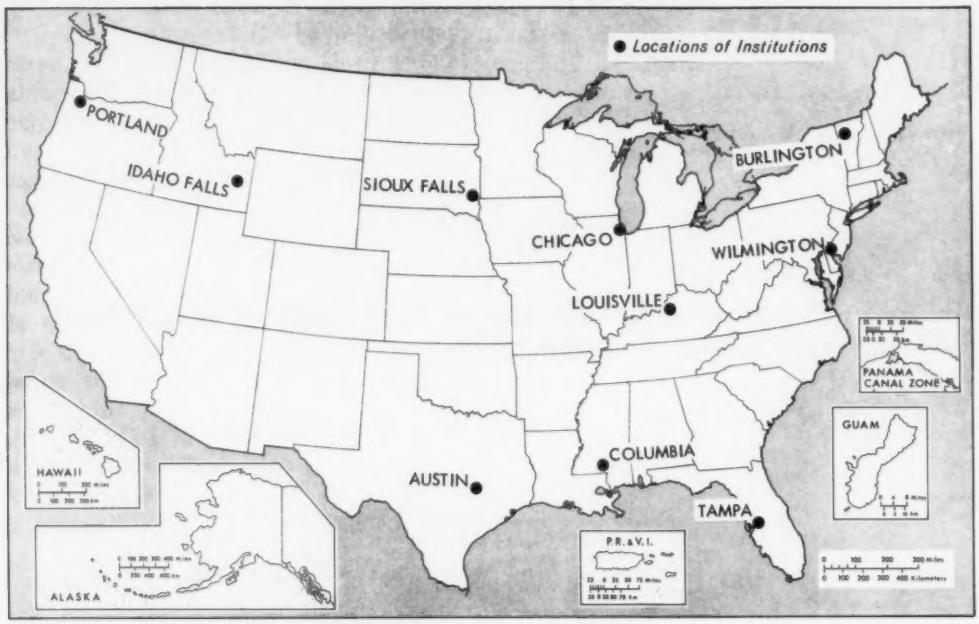

Figure 1. Locations of institutions

None of these is ordinarily present to any significant extent in the urine of healthy individuals; hence, no known discrepancies were due to these factors in this study.

The results of early experiments in this laboratory indicated that substantial errors were introduced if urine specimens were improperly preserved; therefore, particular attention was given to the preservation and handling of the 24-hour urine samples.

Results and discussion

Urinary constants were measured for their contribution to the validation of a 24-hour sample. The normal values for many of these parameters, particularly under conditions of this study, were largely unknown. It was hoped that information gained by combination of these parameters could be used to establish the validity of values reported.

In all cases, the values were separately averaged for males and females and for various ages. Values below 1 standard deviation from the mean were discarded but those above 1 standard deviation were retained. It was reasoned that excessively high values were probably caused by physiological factors while excessively low values were indicative of an incomplete sample collection. Obviously, this approach is subject to dispute. However, as can be seen in the majority of the cases studied, the cause for discarding a sample was that more than one factor, e.g., creatinine and volume, did not meet the criteria mentioned above.

Creatinine

The use of creatinine values for the validation of a 24-hour urine sample has been reported in the past (*9–12*). Creatinine is the end product of creatine catabolism, and excreted creatinine is a measure of the basal nitrogen catabolism. An adult man excretes 3 to 6 percent of total urinary nitrogen daily as creatinine, and the creatinine excretion is relatively constant from day to day for a given individual on a normal diet. However, several factors may affect creatinine excretion. For

example, a heavy meat diet contains significant amounts of creatinine, which is not metabolized and is excreted rapidly. Creatinine in the diet is excreted unchanged in urine.

The constancy of true or endogenous creatinine excretion in the urine is not affected significantly by moderate changes in protein intake. However, creatinine in urine of persons on a normal diet may be elevated when renal function is impaired, as it depends on rate of urine formation and rate of elimination of urine. Serious renal impairment is indicated, for example, in disease states such as typhoid, tetanus, or pneumonia, where an increase in creatinine excretion would occur. A decrease in urinary creatinine would be observable in muscular atrophy, anemia, kidney degeneration, and leukemia. It is stressed, however, that measurements outside normal ranges do not necessarily indicate disease.

Creatinine excretion increases with age to adulthood, and is somewhat higher in obese persons than in thin persons (*13–15*). The creatinine measurement has been proven to be of greatest value in determining the completeness of urinary output and provides an index of glomerular filtration.

The problem of the validation of a 24-hour urine sample was complicated in this study by lack of control during sample collection and shipment. Although attempts have been made to relate urinary excretion rate to the creatinine level of a one-voiding sample (*10*), this approach would be questionable without reference to other criteria for children of the age groups of this study due to rapid changes in the metabolism of this age group.

Cahill and Wheeler (*3*) report normal creatinine values ranging from 0.4 to 1.7 g/day for children. Values of Clark, et al. (*16*), range from 0.50 to 1.90 g/day for ages 6 to 18. O'Brien and Abbott (*17*) related creatinine excretion to body weight of children, ages 12 to 17 as follows: females, 22.8 mg/kg (range 12.2–29.4); males, 25.1 mg/kg (range 20.7–28.2).

Klimakova (*18*) reported creatinine excretion values for 118 children, ages 7 to 16, on a special diet in which eggs, milk and curd replaced meat and fish. During maturation

Table 1. Creatinine in urine excreted by children (g/day)

Age	Male								Female							
	Number of samples	High	Low	Mean	Standard deviation	Others		Reference	Number of samples	High	Low	Mean	Standard deviation	Others		Reference
						Mean	Standard deviation							Mean	Standard deviation	
7	3	0.55	0.20	0.33	0.19			(*)								
						0.50	0.10	16						0.54	0.12	16
8	7	.95	.29	.54	.22			(*)	1			0.81				(*)
9	24	1.52	.20	.72	.30			(*)	4	1.06	0.45	.67	0.31			(*)
						.69	.11	16						.59	.11	16
10	38	2.76	.14	.69	.48			(*)	10	1.22	.27	.61	.28			(*)
7–10						.48		18						.43		18
11	62	2.28	.04	.76	.40			(*)	24	1.34	.19	.60	.30			(*)
					.45	.21		19						.30	.15	19
					.83	.19		16						.80	.17	16
12	55	2.25	.05	.80	.44			(*)	18	2.78	.47	.97	.51			(*)
					.52	.23		19						.40	.27	19
13	12	1.52	.28	.76	.43			(*)	11	1.53	.32	.97	.36			(*)
						.66	.30	19						.33	.18	19
						.10	.29	16						.95	.19	16
1–13						.73		18						.70		18
14	16	4.51	.37	1.76	.98			(*)								
						.68	.36	19						.43	.36	19
15	45	3.69	.19	1.42	.74			(*)	2	1.29	.99	1.14	.21			(*)
						.86	.31	19						.43	.17	19
						1.50	.32	16						1.20	.18	16
16	57	2.81	.15	1.46	.55			(*)								
						.83	.34	19						.55	.24	19
14–16						1.08		18						.98		18
17	56	2.92	.08	1.38	.57			(*)								
						1.90	.32	16						1.20	.18	16
17–18						.85	.38	19						.60	.28	19
18	4	2.00	1.70	1.70	.22			(*)								

* This paper.

daily urinary creatinine excretion increased. Contrasting results were obtained from 10 physically underdeveloped children. The urinary creatinine excretion of this group was lower than that of healthy children of the same age group. This study indicates the effect of nutrition and diet on urinary creatinine values, tends to explain the wide range of observed values.

Zorab (*19*) found that in children of both sexes, the mean creatinine excretion increased steadily with age, and between 11 and 18 years, the value doubled. Zorab's measurements were obtained from over 1,000 samples from children on a 24-hour collagen-free diet (withholding of ice cream, fish and meat). Banchieri (*20*) concluded that creatinine excretion is solely a function of body weight.

Table 1 shows the creatinine content of the samples collected, expressed as average value, range, and standard deviation. Figure 2 reflects graphically the data plotted by age and sex. For comparison, the figure also includes data from selected authors who have reported creatinine values for children (*16,18,19*). The data indicated no distinct influence of sex in early years, but an apparent divergence in later years of youth. Harding and Gaebler (*9*) previously reported this divergence in creatinine values during the teen years.

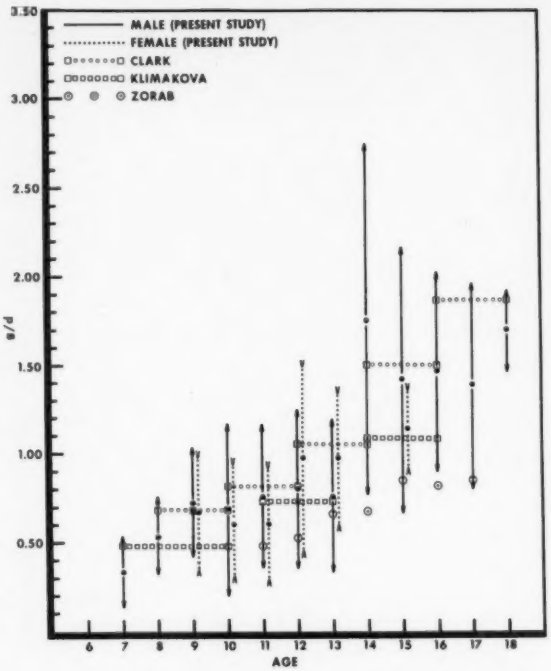

Figure 2. Urinary creatinine observations of children 7 to 18 years, compared with mean value reported by Clark and Thompson (*16*), Klimakova (*18*), and Zorab (*19*), (mean and mean ± standard deviation)

Volume

Although urine volume alone is an unreliable parameter for the validation of a sample, in combination with other parameters it is useful (*7, 19, 22*). Table 2 lists the volumes of urine collected in this study. Plotting of the data by age (figure 3) indicates little deviation from values reported previously. Normal urine volume for children 5 to 8 years of age as reported by Nelson, et al. (*24*), is 650–1,000 ml/day; for 8 to 14 years of age, 800–1,000 ml/day. Rourke, et al. (*25*), reported average values of 1,200 ml/day, ranging from 500–3,000 ml/day.

In some cases, a very low creatinine value is associated with a small sample volume, indicating an incomplete collection. There are also examples of disagreement between the two parameters. A large sample volume and a small creatinine value could be attributed to a possible addition of water to the sample by the child to satisfy the person in charge of the institution, and a reasonable creatinine value with a small sample volume may be attributed to a decrease in the water intake of the individual. In this report, samples having a volume lower than the mean less 1 standard deviation have been eliminated from further evaluation. In the majority of cases, these samples would also have been disregarded due to the low creatinine content.

Covariance analysis was performed where the volume of each sample was related to the creatinine value obtained. The resulting coefficients were plotted by age and sex. Figure 4 indicates that this relationship increases with age.

Table 2. Volume of urine excreted by children (ml/day)

Age	Male					Female				
	Number of samples	High	Low	Mean	Standard deviation	Number of samples	High	Low	Mean	Standard deviation
7	3	790	455	680	190	—	—	—	—	—
8	7	900	150	560	260	1	—	—	430	—
9	27	2,000	170	640	380	4	1,760	480	940	550
10	43	1,820	125	700	360	12	1,300	240	710	330
11	64	1,580	90	730	380	25	1,300	120	610	340
12	59	2,082	120	840	460	18	1,900	390	890	380
13	12	3,400	150	1,200	1,000	12	1,340	440	840	290
14	21	3,888	660	1,400	760	—	—	—	—	—
15	45	2,252	415	1,200	490	2	650	620	640	210
16	59	3,075	425	1,200	550	—	—	—	—	—
17	60	3,580	360	1,200	750	—	—	—	—	—
18	4	2,900	900	1,700	960	—	—	—	—	—

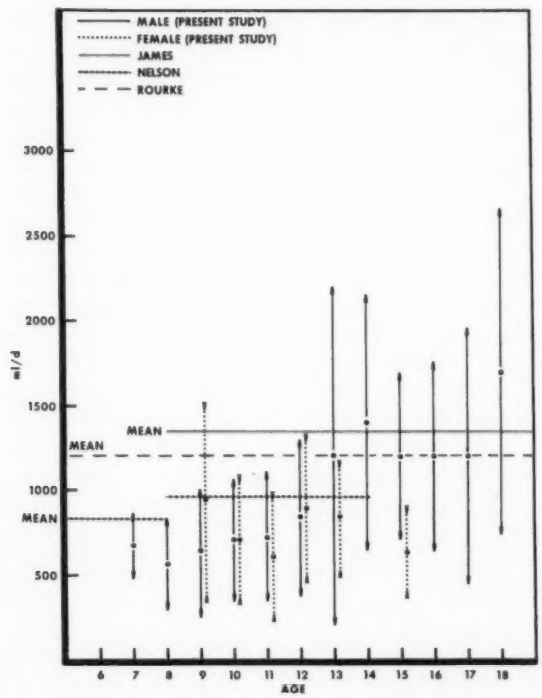

Figure 3. Results of urine volume measurements of children 7 to 18 years, compared to mean value reported by James (23), Nelson et al. (24), and Rourke et al. (25) (mean and mean ± standard deviation)

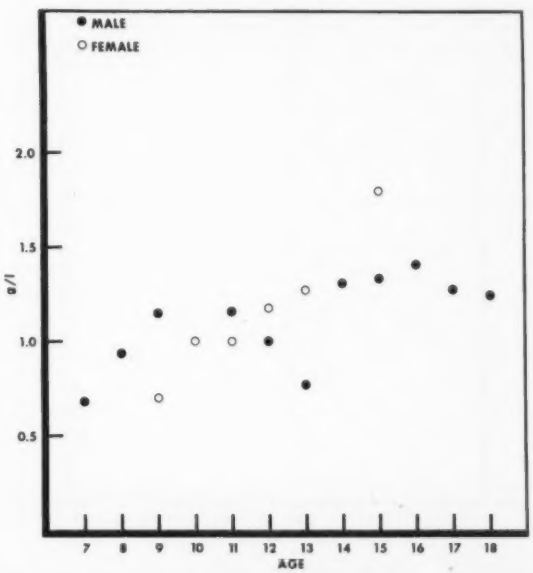

Figure 4. Excretion of creatinine by children expressed in g/liter

Specific gravity and osmolality

Normal specific gravity measurements fall in the range of 1.002–1.025, with the average value at 1.018 for children (*22–26, 27*). Table 3 lists the specific gravity determinations and figure 5 shows them graphically. The stability of the specific gravity in urine is remarkable and in combination with other parameters such as volume, is used to validate the sample. A high volume and a low specific gravity indicate a possible dilution of the sample with water. In several cases, this could be observed and was combined with a low creatinine value. The combination of volume and specific gravity could be used only on a confirmatory basis as high water excretion is usually associated with low salt concentration.

Table 3. Specific gravity of urine excreted by children

Age	Male					Female				
	Number of samples	High	Low	Mean	Standard deviation	Number of samples	High	Low	Mean	Standard deviation
7	3	1.033	1.015	1.023	0.009	—	—	—	—	—
8	7	1.034	1.018	1.027	.006	1	—	—	1.021	—
9	27	1.032	1.015	1.022	.005	4	1.025	1.014	1.019	0.004
10	43	1.033	1.010	1.021	.005	12	1.032	1.005	1.020	.007
11	64	1.035	1.005	1.022	.007	25	1.032	1.010	1.022	.006
12	59	1.030	1.009	1.020	.005	18	1.030	1.009	1.021	.004
13	12	1.030	1.006	1.018	.007	12	1.029	1.017	1.022	.005
14	21	1.030	1.010	1.019	.006	—	—	—	—	—
15	45	1.035	1.004	1.019	.008	2	1.034	1.032	1.033	.001
16	59	1.033	1.004	1.021	.006	—	—	—	—	—
17	60	1.035	1.002	1.020	.007	—	—	—	—	—
18	4	1.030	1.010	1.021	.008	—	—	—	—	—

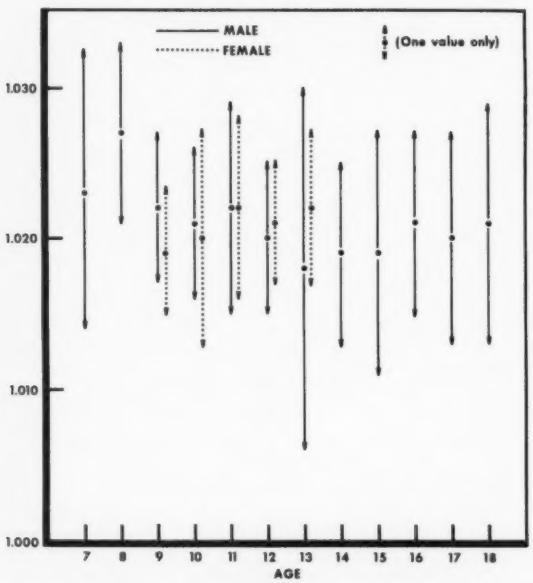

Figure 5. Specific gravity results in urine of children 7 to 18 years (mean and mean ± standard deviation)

Closely associated with specific gravity is the osmolality. By definition, the osmolality of a given solution is numerically equal to the molality of an ideal solution of a nonelectrolyte having the same freezing point. Korte (*28*) suggested that since the osmolality of urine is influenced by the intake of electrolytes and the content of nitrogen-containing compounds in urine, osmolality ratios in nutritional field studies may prove to be more constant than creatinine values which are dependent on muscle mass development. This observation was based on the fact that the intake and output of electrolytes are well balanced and constant in most communities of developing countries.

Osmolality results of this study are shown in table 4. Graphic presentation of the data is shown in figure 6. Normal osmolality measurements range from 515 mOs/liter for infants to an average value of 1,362 for 14 to 18-year olds (*29, 30*).

Table 4. Osmolality of urine excreted by children (mOs/liter)

Age	Male					Female				
	Number of samples	High	Low	Mean	Standard deviation	Number of samples	High	Low	Mean	Standard deviation
7	3	1,250	613	860	340	—	—	—	—	—
8	4	995	824	920	73	1	—	—	770	—
9	15	1,950	500	880	400	3	809	522	660	140
10	26	1,700	190	790	340	2	3,200	814	2,000	1,700
11	41	3,100	171	1,100	700	8	2,750	699	1,300	720
12	19	1,035	348	700	190	12	1,150	640	800	150
13	10	1,125	275	680	290	3	1,600	791	1,100	430
14	12	1,800	210	800	470	—	—	—	—	—
15	25	3,300	210	830	750	2	3,100	1,500	2,300	1,130
16	32	1,950	110	760	390	—	—	—	—	—
17	36	2,900	130	830	640	—	—	—	—	—
18	2	650	303	480	240	—	—	—	—	—

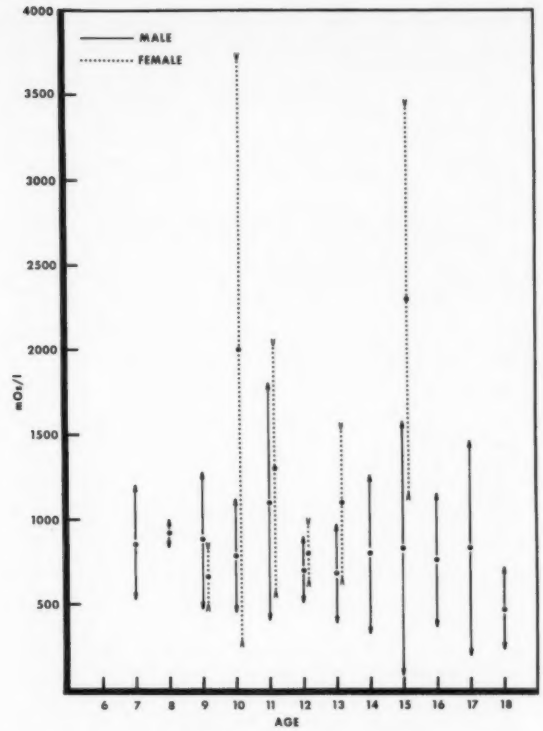

Figure 6. Osmolality in urine of children 7 to 18 years (mean and mean ± standard deviation)

pH Value

Because the pH value changes with metabolism and biological activity after the sample collection, conclusions regarding the relationship between the pH value and the validity of the sample are dubious. In the present study an attempt was made to properly preserve the samples and thus the pH values may be of greater value than from improperly preserved samples. The determination of urinary pH is of importance clinically, largely in relation to the precipitation of insoluble material from urine and possible formation of urinary calculi. The normal pH range values for man are 4.8 to 8.0 (*25*). Table 5 and figure 7 include the pH observations for ages 6 to 18 in this study and indicate agreement with previously reported values.

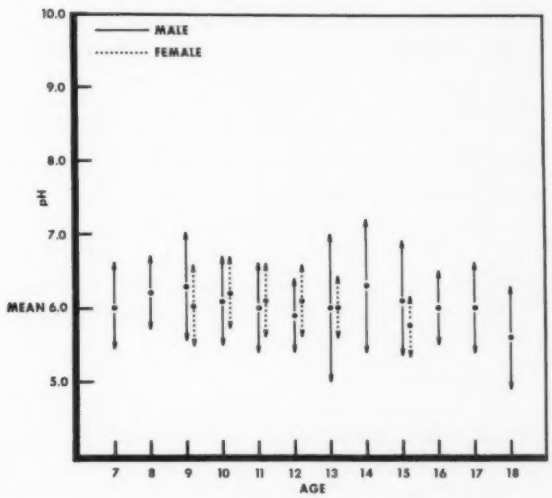

Figure 7. Urine pH measurements of children 7 to 18 years (mean and mean ± standard deviation)

Table 5. pH of urine excreted by children

Age	Male					Female				
	Number of samples	High	Low	Mean	Standard deviation	Number of samples	High	Low	Mean	Standard deviation
7	3	6.7	5.7	6.03	0.58	—	—	—	—	—
8	8	6.6	6.1	6.23	.49	1	—	—	6.40	—
9	25	9.0	5.4	6.28	.74	4	6.6	5.4	6.05	0.59
10	41	7.9	4.8	6.07	.61	10	6.9	5.3	6.19	.46
11	61	8.4	5.0	5.98	.55	23	6.8	5.4	6.13	.42
12	53	7.0	4.5	5.85	.56	18	6.8	5.3	6.14	.46
13	12	8.8	4.9	6.0	1.0	11	6.7	5.6	6.03	.34
14	17	9.7	5.6	6.29	.94	—	—	—	—	—
15	45	9.8	5.0	6.09	.83	2	6.0	5.5	5.75	.35
16	58	7.0	5.0	6.00	.48	—	—	—	—	—
17	58	8.3	5.0	6.02	.60	—	—	—	—	—
18	4	6.2	4.8	5.58	.68	—	—	—	—	—

Conclusions

It is evident that the measurement of urinary parameters is valuable for radiobioassay studies in children. Creatinine determination has been used in the present study as the most important single factor in the validation of a 24-hour urine sample.

Volume, osmolality, and specific gravity are other useful parameters which were used to confirm conclusions based on creatinine values. The pH determination was performed to evaluate the condition of urine and, in some instances, as a basis for elimination of sample data obtained from children with health disorders. The combined values determined for these samples indicate that a 24-hour sample can be validated, provided previously reported data are used in combination as "normal values." Sixty-two samples were eliminated from consideration on the basis of a combination of constants, 14 on the basis of volume alone, and 27 solely on the creatinine value.

Upon further investigation, the use of osmolality as a urinary constant may prove to be of greater value than considered here although insufficient data were available for a conclusive evaluation.

Acknowledgement

The authors wish to express appreciation to Mr. Robert Lieberman, Mrs. Mae Williams, Mrs. Johnie Johnson, and Mrs. Ann Strong for assistance during this study; to Mr. Brian K. Spavin for preparation of figures; to Mrs. Vicki Peterson for calculations.

REFERENCES

(*1*) ANDERSON, E. C. and D. J. NELSON, JR. Surveillance for radiological contamination in food. Amer J Pub Hlth 52:139 (1962). See also *Radiation Data and Reports* for continuous updating of ITDSN.

(*2*) MOGHISSI, A. A., M. W. CARTER, and R. LIEBERMAN. Radiobioassay program of the Institutional Total Diet Sampling Network—I. Analytical data related to samples collected during 1966–1968. Radiat Data Rep 14:129–144 (March 1973).

(*3*) CAHILL, D. F., and J. K. WHEELER. The biological half-life of cesium-137 in children, determined by urinary assay. Health Phys 14:293–297 (1968).

(*4*) MOGHISSI, A. A., and R. LIEBERMAN. Tritium body burdens of children, 1967–1968. Radiol Hlth Data Rep 11:227–231 (May 1970).

(*5*) FOLIN, O. Determination of creatinine and creatine in urine. J Biol Chem 17:469 (1914).

(*6*) CLARK, L. C., JR., and H. L. THOMPSON. Determination of creatine and creatinine in urine. Anal Chem 21:1218 (October 1949).

(*7*) WATKINS, P. J. The effect of ketone bodies on the determination of creatinine. Clin Chem Acta 18:191 (1967).

(*8*) HUSDAN, H., and A. RAPOPORT. Estimation of creatinine by the Jaffe reaction. Clin Chem 14:322 (March 1968).

(*9*) HARDING, V. J., and O. H. GAEBLER. On the constancy of the creatine-creatinine excretion in children on a high protein diet. J Biol Chem 54:579 (1922).

(*10*) JACKSON, S. Creatinine in urine as an index of urinary excretion rate. Health Phys 12:843 (1966).

(*11*) EDWARDS, O. M., R. BAYLISS, and S. MILLEN. Urinary creatinine excretion as an index of the completion of 24-hour urine collections. Lancet 2: 1165–1166 (1969).

(*12*) HAMBURGER, J. Nephrology, Chapter 5. W. B. Saunders Company, Philadelphia (1966).

(*13*) CHINN, K. S. K. Prediction of muscle and remaining tissue protein in man. J Appl Physiol 23:713 (1967).

(*14*) BEHRENDT, H. Creatine and creatinine in diagnostic tests in infants and children. Lea and Febiger, Philadelphia (1962) pp. 162–167.

(*15*) NOVAK, L. P. Age and sex differences in body density and creatinine excretion of high school children. Ann N.Y. Acad Sci 110:545–577 (1963).

(*16*) CLARK, L. C., H. L. THOMPSON, E. I. BECK, and W. JACOBSON. Excretion of creatine and creatinine by children. Amer J Dis Child 81:774 (1951).

(*17*) O'BRIEN, B., and F. A. ABBOTT. Creatinine and creatine in urine. Laboratory Manual of Pediatric Micro and Ultramicro Biochemical Techniques, 3rd Edition. Harper and Row Company, New York (1962) p. 100.

(*18*) KLIMAKOVA, A. I. Creatinine metabolism as a development index of the muscular system in children. Tr Nauchn Konf Po Vozrastnoi Morfol, Fiziol i Biokhim, 6th:336, Moscow (1965).

(*19*) ZORAB, P. A. Normal creatinine and hydroxyproline excretion in young persons. Lancet 2:1164 (1969).

(*20*) BANCHIERI, G. C. Creatininuria and creatinuria in relation to age, sex, and various pathological conditions. Giorn Gerontol 16:653–664 (1968).

(*21*) OAKLEY, B. W. Urinary excretion rates of creatinine, UKAEA Document AERE MED/R 2098 (1956).

(*22*) ELKINS, H. B. The specific gravity adjustment in urinalysis. Arch Environ Hlth 18:996–1001 (1969).

(*23*) JAMES, J. A. Renal disease in childhood, Chapter 5. C. V. Mosby Co., St. Louis, Mo. (1968).

(*24*) NELSON, W. E., V. C. VAUGHAN, III, and R. J. McKAY, Eds. Textbook of Pediatrics, 9th Edition. W. B. Saunders, Philadelphia (1969) p. 210.

(*25*) ROURKE, G. M., E. A. MacLACHLAN, and A. M. BUTLER. Case records of the Massachusetts General Hospital normal laboratory values. New Eng J Med 234:24 (1946).

(*26*) MERRILL, J. P. Normal and abnormal renal function. Urology, 2nd Edition. W. B. Saunders and Company, Philadelphia (1963) p. 51.

(*27*) Massachusetts General Hospital "normal values." New Eng J Med 283:1279 (1970).

(*28*) KORTE, R. Urinary creatinine excretion. Amer J Clin Nutr 23:868 (July 1970).

(29) POLACEK, E. The osmotic concentration ability in healthy infants and children. Arch Dis Child 40:211, 291–295 (1965).

(*30*) CORCORAN, A. C. Electrometrics urinometry: a note on comparative determinations of urinary osmolarity and specific gravity. J. Lab Clin Med 46:141 (1955).

Radiobioassay Program of the Institutional Total Diet Sampling Network III. Cesium-137 Dose Estimates and Body Burdens of Children

A. A. Moghissi and Mary G. Mayes [1]

Food and urine samples collected from ten stations of the Institutional Total Diet Sampling Network program were analyzed. Cesium-137 and potassium in food and urine were analyzed by gamma spectroscopy. The cesium-137 body burdens were established by using the cesium-to-potassium ratio, by the relationship between cesium content of urine and the biological half-life of cesium in children, and by a model based on intake.

Differences among results obtained, using each of these techniques, are discussed. Radiation dose calculations are based on recommendations in International Commission on Radiation Protection Report Number 2.

A description, discussion of objectives, and the analytical results of the Institutional Total Diet Sampling Network (ITDSN) program have been published and are continuously updated (*1*). Also, essential features of the radiobioassay portion of the ITDSN program have been described (*2-4*). Data concerning the urinary constants measured during the years 1966–1968 are detailed in this issue of *Radiation Data and Reports*. (*5*). This report deals with the discussion of the results of studies on the cesium-137 body burdens of children, and the resulting radiation dose to muscle, liver, and bone.

Since intake and urinary excretion data on a large number of subjects within the ITDSN have been determined, an opportunity is provided for estimating the cesium-137 body burden by a variety of calculation techniques.

Rehnberg, et al., (*6*) have estimated the body burden of children using the following equation:

$$Q = 10^{-3} f \sum_{i=1}^{i=n} I^{t_b/0.693} (1 - e^{-0.693\, t_m/t_b})\, e^{-0.693\, t_d/t_b} \quad \ldots (1)$$

where: Q = the cesium-137 body burden in nCi,

f = the fraction of cesium-137 absorbed from the GI tract,

I = the intake of cesium-137 per day,

t_b = the biological half-life of cesium,

t_m = the reporting period for intake values (1 month), and

t_d = the period between end of i^{th} period and period of the body burden estimation.

The available total diet results permit an estimation of the body burden using equation (1).

A second possibility for the estimation of body burden is the application of the following equation:

$$t_b = 0.693\, Q \frac{F_u}{U} \quad \ldots (2)$$

where:

Q and t_b have the same notations as in equation (1),

F_U = the fraction of cesium-137 excreted in urine, and

U = the average cesium-137 activity in urine in nCi/day.

The estimation based on equation (2) is particularly useful as the t_b of 53 days was determined (*2*) using the same procedures employed to obtain data from the subjects covered by this study.

Several investigations have compared the $^{137}Cs/K$ in food to that in the body. McNeill and Trojan (*6*), e.g., propose the following equation:

$$(^{137}Cs/K)_{body} = 3\, (^{137}Cs/K)_{food} \quad \ldots (3)$$

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Oberhausen and Onstead (*7*) have measured the potassium values in children. Their extensive values are generally in agreement with previously reported results (*8*). Using those results and $(^{137}Cs/K)_{body}$, the body burden can be estimated.

The comparison between the results from the three above-mentioned methods permits an evaluation of errors associated with cesium body burden determinations in children by methods other than the direct measurement, i.e., whole body counting.

Based on the body burdens estimated and reported in this paper, dose estimates were calculated according to the International Commission on Radiation Protection (ICRP) model (*9*) and are presented following body burden information.

Procedures and methods

The details of sample collection and analysis, dietary habits and other factors influencing the cesium intake in the ITDSN have been described previously (*1*). The radiobioassay portion of ITDSN for 1966, including the details and analysis and the procedures for validation of 24-hour urine samples, was reported by Cahill and Wheeler (*2*). These procedures have continued to be followed except for the addition of an osmolality factor. Considerable effort was made to validate the 24-hour urine collection. The highest reliance was placed on creatinine content as this parameter seems to be relatively independent of the intake. Volume, pH-value, and specific gravity were used as supplementary evidence (*4*). All samples were analyzed by gamma spectroscopy as previously described (*2*).

Results and discussions

Tables 1 to 3 show the body burdens of children from selected institutions in the United States during 1966 to 1968.

The body burden estimation by the biological half-life method is reported under t_b and was calculated according to equation (2) using a urine to total excretion ratio of 0.8 (*2*) and a t_b of 53 days.

The body burden by food intake (F) was calculated using equation (1). Due to the incomplete sample collection during the year, the average value for each year was used in the calculation process to replace the missing months. The application of equation (3) in association with potassium values is reported in the column designated Cs/K. Finally, the average of the results obtained by three methods is also included.

Table 1. Cesium-137 body burden of children during 1966 (nCi)

Station		t_b[a]	Cs/K[b]	F[c]	Average
Tex:	Austin	[d](11) 1.5	1.2	1.6	1.4
Miss:	Columbia	4.4	—	—	4.4
Del:	Wilmington	(10) 3.4	1.9	(11) 3.9	3.1
Idaho:	Idaho Falls	(10) 4.0	4.2	5.0	4.4
Vt:	Burlington	(11) 3.4	2.9	3.3	3.2
Oreg:	Portland	(9) 5.4	5.8	(11) 4.4	5.2
Ky:	Louisville	(7) 2.5	1.8	(10) 2.3	2.2
Ill:	Chicago	3.2	2.4	2.7	2.8
S. Dak:	Sioux Falls	(6) 2.7	3.3	(6) 6.6	4.2
Fla:	Tampa	(11) 7.2	4.0	9.9	7.0
Average		3.8	3.0	4.4	

[a] Calculated by the biological half-life.
[b] Calculated by the cesium-to-potassium ratio.
[c] Calculated from the food intake.
[d] Number of months per year for which samples were available.

Table 2. Cesium-137 body burden of children during 1967 (nCi)

Station		t_b[a]	Cs/K[b]	F[c]	Average
Tex:	Austin	1.0	0.4	0.1	0.50
Miss:	Columbia	2.3	—	—	2.3
Del:	Wilmington	2.5	.9	1.7	1.7
Idaho:	Idaho Falls	3.0	1.7	2.1	2.3
Vt:	Burlington	[d](6) 1.0	1.1	(8) 2.2	1.4
Oreg:	Portland	2.9	2.5	2.5	2.6
Ky:	Louisville	(11) .8	.7	.4	.6
Ill:	Chicago	(11) 2.0	1.2	2.0	1.7
S. Dak:	Sioux Falls	—	—	—	—
Fla:	Tampa	(11) 3.4	2.2	7.3	4.3
Average		2.1	1.3	2.3	

[a] Calculated by the biological half-life.
[b] Calculated by the cesium-to-potassium ratio.
[c] Calculated from the food intake.
[d] Number of months per year for which samples were available.

Table 3. Cesium-137 body burden of children during 1968 (nCi)

Station		t_b[a]	Cs/K[b]	F[c]	Average
Tex:	Austin	—	—	—	—
Miss:	Columbia	2.1	1.8	1.8	1.9
Del:	Wilmington	[d](11) 1.2	.4	.7	.8
Idaho:	Idaho Falls	(11) 3.4	2.0	3.0	2.8
Vt:	Burlington	—	—	—	—
Oreg:	Portland	3.2	1.7	(1) 1.2	2.0
Ky:	Louisville	1.1	—	—	1.1
Ill:	Chicago	(6) 1.2	1.2	(6) 1.8	1.4
S. Dak:	Sioux Falls	—	—	—	—
Fla:	Tampa	(1) 2.7	1.8	3.4	2.6
Average		2.1	1.5	2.0	

[a] Calculated by the biological half-life.
[b] Calculated by the cesium-to-potassium ratio.
[c] Calculated from the food intake.
[d] Number of months per year for which samples were available.

It can be seen that the deviation of the results of each method from the average is reasonably small if one considers the errors associated with this type of study. The largest errors are introduced by the low levels of cesium in food and urine and large analytical errors associated with some of the results.

An additional source of error in the results obtained from the cesium to potassium ratio is the uncertainty regarding the potassium body burden of children. Obviously, the average potassium values used for the calculation can deviate markedly from the potassium body burden of children in this study.

All cesium-137 results below the minimum limit of detection of 10 pCi/kg were recorded as zero. It is obvious that this procedure causes discrepancies in individual results. During the averaging process, these inaccuracies tend to be minimized and thus the calculated annual average body burdens by the biological half-life method and the food intake method agree reasonably well. For 1966, the values were 3.8 nCi and 4.4 nCi, respectively. For 1967, these values were 2.1 nCi and 2.3 nCi, and for 1968, 2.1 nCi and 2.0 nCi. The values calculated from the cesium-to-potassium ratio for the same years are 3.0 nCi, 1.3 nCi, and 1.5 nCi, respectively. These averages are lower than values calculated by other techniques, although in no case do they deviate by more than a factor of 2 from values calculated by the two other methods.

Results obtained from the Austin station in 1967 are indicative of the effect of the analytical errors. While all urine values were above the minimum limit of detection, six food values were below the limit of detection and thus were recorded as zero. This explains the 10-fold difference between the body burdens estimated by the biological half-life and food intake methods, respectively.

It is concluded that the body burden estimation by any one of the above mentioned techniques is valid for the evaluation of population exposure provided a sufficiently large number of samples are available. In many cases, the whole body counting technique is not sensitive enough to measure the body burden in the general population and one is forced to use techniques based on intake or excretion. If reasonable sample collection and analytical techniques are used, the results of these cesium body burden estimates are valid and are accurate within a factor of 2 or less.

Table 4 summarizes the results of dose estimates by geographic location and by year using the ICRP model (*9*).

Table 4. Average estimated dose from cesium-137 by geographic location (mrem/a)

Location		Tissue	1966	1967	1968
Tex:	Austin	Muscle	0.8	0.3	NA
		Liver	1.2	.4	NA
		Bone	.6	.2	NA
Miss:	Columbia	Muscle	1.5	.8	0.6
		Liver	2.1	1.1	.9
		Bone	1.1	.5	.5
Ky:	Louisville	Muscle	1.0	.3	.6
		Liver	1.5	.4	.9
		Bone	.7	.2	.4
Ill:	Chicago	Muscle	1.3	.8	.7
		Liver	1.9	1.2	1.0
		Bone	1.0	.6	.5
S. Dak:	Sioux Falls	Muscle	2.2	NA	NA
		Liver	3.1	NA	NA
		Bone	1.6	NA	NA
Del:	Wilmington	Muscle	1.7	.9	.5
		Liver	2.3	1.3	.7
		Bone	1.2	.7	.3
Idaho:	Idaho Falls	Muscle	1.5	.8	1.0
		Liver	2.1	1.1	1.4
		Bone	1.1	.6	.7
Vt:	Burlington	Muscle	1.7	.7	NA
		Liver	2.4	1.1	NA
		Bone	1.2	.5	NA
Oreg:	Portland	Muscle	1.8	.9	.7
		Liver	2.5	1.3	1.0
		Bone	1.3	.7	.5
Fla:	Tampa	Muscle	3.7	2.3	1.5
		Liver	5.3	3.3	2.1
		Bone	2.7	1.7	1.1

NA, no analysis, data not available.

The estimated dose to muscle from cesium-137 was highest in Tampa, Fla., for each of the 3 years under study. This is in agreement with findings of Karches, et al. (*10*). The highest value was in 1966, 3.7 mrem/a, decreasing in 1967 to 2.3 mrem/a. In 1968, the estimated dose to muscle at the Florida sampling station again decreased, to 1.5 mrem/a. All other sampling sites except South Dakota had values of less than 2 mrem/a in 1966; in 1967, less than 1 mrem/a; and in 1968, most decreased again. Estimation of dose to liver from dietary cesium-137 in 1966 was calculated to be 5.3 mrem/a in Florida, and ranged from 3.1 mrem/a in South Dakota to less than 2 mrem/a at other stations.

The estimated dose to bone from cesium-137 in mrem/a was calculated to be 2.7 at Tampa, Fla., the highest value in 1966. All other stations' estimates of dose to bone in 1966 from cesium-137 were <1 mrem/a. As expected, the muscle and bone doses indicated a decreasing trend during the period covered by this study.

REFERENCES

(*1*) ANDERSON, E. C. and D. J. NELSON, JR. Surveillance for radiological contamination in food. Amer J Pub Hlth 52:139 (1962). See also *Radiation Data and Reports* for continuous updating of ITDSN.

(*2*) CAHILL, D. F. and J. K. WHEELER. The biological half-life of cesium-137 in children, determined by urinary assay. Health Phys 14:239 (1968).

(*3*) MOGHISSI, A. A., M. W. CARTER, and R. LIEBERMAN. Radiobioassay Program of the Institutional Total Diet Sampling Network: I. Analytical data related to samples collected during 1966–1968. Radiat Data Rep 14:129–144 (March 1973).

(*4*) MOGHISSI, A. A. and M. G. MAYES. Radiobioassay program of the Institutional Total Diet Sampling Network: II. Selected physiological constants of urine. Radiat Data Rep, this issue.

(*5*) REHNBERG, G. L., C. R. PORTER, and B. KAHN. Estimation of cesium-137 body burden in children. Health Phys (in press).

(*6*) McNEIL, K. G. and O. A. D. TROJAN. The cesium discrimination ratio. Health Phys 4:109 (1960).

(*7*) OBERHAUSEN, E. and C. O. ONSTEAD. Relationship of potassium content of man with age and sex. Radioactivity in Man, G. R. Meneely and S. M. Linde, Editors. Charles C. Thomas, Springfield, Ill. (1965). See also contributions of Remenchick, et al. and Anderson in the same book.

(*8*) ANDERSON, E. C. and W. H. LANGHAM. Average potassium concentration of the human body as a function of age. Science 130:713 (1959).

(*9*) INTERNATIONAL COMMISSION ON RADIATION PROTECTION. Permissible dose for internal radiation, ICRP Report No. 2. Pergamon Press, New York, N.Y. (1959).

(*10*) KARCHES, G. J., J. K. WHEELER, G. L. HEGELSON, and B. KAHN. Cesium-137 body burdens and biological half-life in children in Tampa, Florida, and Lake Bluff, Illinois. Health Phys 16:301 (1969).

SECTION I. MILK AND FOOD

Milk Surveillance, December 1972

Although milk is only one of the sources of dietary intake of environmental radioactivity, it is the food item that is most useful as an indicator of the general population's intake of radionuclide contaminants resulting from environmental releases. Fresh milk is consumed by a large segment of the population and contains several of the biologically important radionuclides that may be released to the environment from nuclear activities. In addition, milk is produced and consumed on a regular basis, is convenient to handle and analyze, and samples representative of general population consumption can be readily obtained. Therefore, milk sampling networks have been found to be an effective mechanism for obtaining information on current radionuclide concentrations and long-term trends. From such information, public health agencies can determine the need for further investigation or corrective public health action.

The Pasteurized Milk Network (PMN) sponsored by the Office of Radiation Programs, Environmental Protection Agency, and the Office of Food Sanitation, Food and Drug Administration, Public Health Service, consists of 63 sampling stations: 61 located in the United States, one in Puerto Rico, and one in the Canal Zone. Many of the State health departments also conduct local milk surveillance programs which provide more comprehensive coverage within the individual State. Data from 15 of these State networks are reported routinely in *Radiation Data and Reports*. Additional networks for the routine surveillance of radioactivity in milk in the Western Hemisphere and their sponsoring organizations are:

Pan American Milk Sampling Program (Pan American Health Organization and U.S. Environmental Protection Agency)—5 sampling stations

Canadian Milk Network (Radiation Protection Division, Canadian Department of National Health and Welfare)—16 sampling stations.

The sampling locations that make up the networks presently reporting in *Radiation Data and Reports* are shown in figure 1. Based on the similar purpose for these sampling activities, the present format integrates the complementary data that are routinely obtained by these several milk networks.

Radionuclide and element coverage

Considerable experience has established that relatively few of the many radionuclides that are formed as a result of nuclear fission become incorporated in milk (*1*). Most of the possible radiocontaminants are eliminated by the selective metabolism of the cow, which restricts gastrointestinal uptake and secretion into the milk. The five fission-product radionuclides which commonly occur in milk are strontium-89, strontium-90, iodine-131, cesium-137, and barium-140. A sixth radionuclide, potassium-40, occurs naturally in 0.0118 percent (*2*) abundance of the element potassium, resulting in a specific activity for potassium-40 of 830 pCi/g total potassium.

Two stable elements which are found in milk, calcium and potassium, have been used as a means for assessing the biological behavior of metabolically similar radionuclides (radiostrontium and radiocesium, respectively). The contents of both calcium and potassium in milk

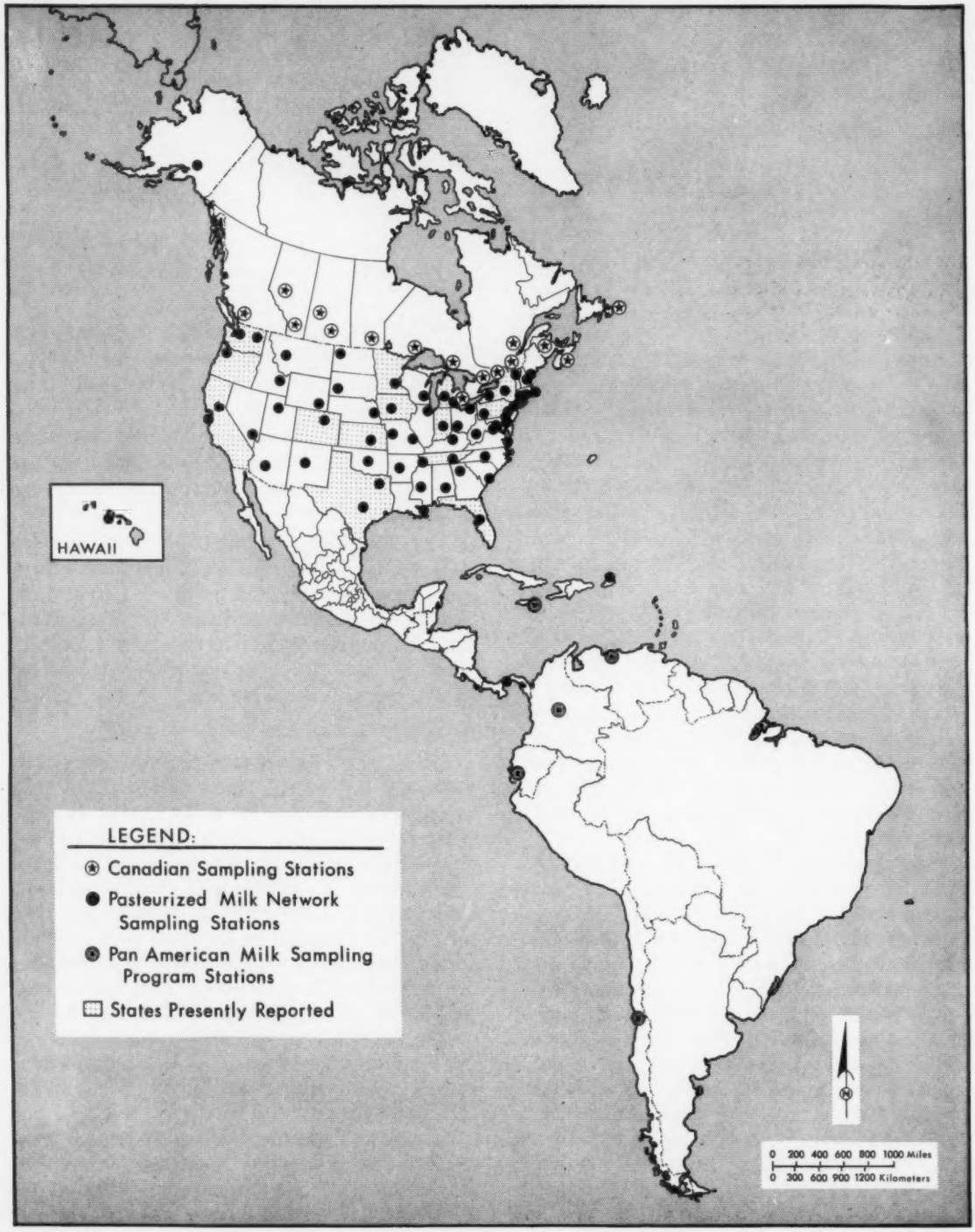

Figure 1. Milk sampling networks in the Western Hemisphere

have been measured extensively and are relatively constant. Appropriate values and their variations, expressed in terms of 2 standard deviations (2σ), for these elements are 1.16 $\pm$ 0.08 g/liter for calcium and 1.51 $\pm$ 0.21 g/liter for potassium. These figures are averages of data from the PMN for May 1963–March 1966 (*3*) and are used for general radiation calculations.

Accuracy of data from various milk networks

In order to combine data from the international, national, and State networks considered in this report, it was first necessary to determine the accuracy with which each laboratory is making its determinations and the agreement of the measurements among the laboratories. The Analytical Quality Control Service of the Office of Radiation Programs conducts periodic studies to assess the accuracy of determinations of radionuclides in milk performed by interested radiochemical laboratories. The generalized procedure for making such a study has been outlined previously (*4*).

The most recent study was conducted during July 1971 with 37 laboratories participating in an experiment on a milk sample containing known concentrations of iodine-131, cesium-137, strontium-89, and strontium-90 (*5*). Of the 17 laboratories producing data for the networks reporting in *Radiation Data and Reports*, 14 participated in the study.

The accuracy results of this study for these 14 laboratories are shown in table 1. Considerable improvement has been made in the accuracy of the analyses of all radionuclides compared to the results of previous studies. Some improvement is still needed in the technique for determining the strontium-90 results. These possible differences should be kept in mind when considering the integration of data from the various networks.

Development of a common reporting basis

Since the various networks collect and analyze samples differently, a complete understanding of several parameters is useful for interpreting the data. Therefore, the various milk surveillance networks that report regularly were surveyed for information on analytical methods, sampling and analysis frequencies, and estimated analytical errors associated with the data.

In general, radiostrontium is collected by an ion-exchange technique and determined by beta-particle counting in low-background detectors, and the gamma-ray emitters (potassium-40, iodine-131, cesium-137, and barium-140) are determined by gamma-ray spectroscopy of whole milk. Each laboratory has its own modifications and refinements of these basic methodologies.

Many networks collect and analyze samples on a monthly basis. Some collect samples more frequently but composite the several samples for one analysis, while others carry out their analyses more often than once a month. Many networks are analyzing composite samples on a quarterly basis for certain nuclides The frequency of collection and analysis varies not only among the networks but also at different stations within some of the networks. In addition, the frequency of collection and analysis is a function of current environmental levels.

Table 1. Distribution of mean results, quality control experiment

Isotope and known concentration	Number of laboratories in each category				Experimental 2σ error (pCi/liter)
	Acceptable [a]	Warning level [b]	Unacceptable [c]	Total	
Iodine-131 (69 pCi/liter)	13 (100%)	0	0	13	6
Cesium-137 (52 pCi/liter)	12 (92%)	1 (8%)	0	13	6
Strontium-89 (31 pCi/liter)	9 (90%)	1 (10%)	0	10	6
Strontium-90 (41.6 pCi/liter)	9 (69%)	1 (8%)	3 (23%)	13	2.4

[a] Measured concentration equal to or within 2σ of the known concentration.
[b] Measured concentration outside 2σ and equal to or within 3σ of the known concentration.
[c] Measured concentration outside 3σ of the known concentration.

The number of samples analyzed at a particular sampling station under current conditions is reflected in the data presentation. Current levels for strontium-90 and cesium-137 are relatively stable over short periods of time, and sampling frequency is not critical. For the short-lived radionuclides, particularly iodine-131, the frequency of analysis is critical and is generally increased at the first measurement or recognition of a new influx of this radionuclide.

The data in table 2 show whether raw or pasteurized milk was collected. An analysis (*6*) of raw and pasteurized milk samples collected during January 1964 to June 1966 indicated that for relatively similar milksheds or sampling areas, the differences in concentration of radionuclides in new and pasteurized milk are not statistically significant (*6*). Particular attention was paid to strontium-90 and cesium-137 in that analysis.

Practical reporting levels were developed by the participating networks, most often based on 2-standard-deviation counting errors or 2-standard-deviation total analytical errors from replicate analyses (*3*). The practical reporting level reflects analytical factors other than statistical radioactivity counting variations and will be used as a practical basis for reporting data.

The following practical reporting levels have been selected for use by all networks whose practical reporting levels were given as equal to or less than the given value.

Radionuclide	Practical reporting level (pCi/liter)
Strontium-89	5
Strontium-90	2
Iodine-131	10
Cesium-137	10
Barium-140	10

Some of the networks gave practical reporting levels greater than those above. In these cases, the larger value is used so that only data considered by the network as meaningful will be presented. The practical reporting levels apply to the handling of individual sample determinations. The treatment of measurements equal to or below these practical reporting levels for calculation purposes, particularly in calculating monthly averages, is discussed in the data presentation.

Anaytical error or precision expressed as pCi/liter or percent in a given concentration range has also been reported by the networks (*3*). The precision errors reported for each of the radionuclides fall in the following ranges:

Radionuclide	Analytical errors of precision (2-standard deviations)
Strontium-89	1–5 pCi/liter for levels <50 pCi/liter; 5–10% for levels ≧ 50 pCi/liter;
Strontium-90	1–2 pCi/liter for levels <20 pCi/liter; 4–10% for levels ≧ 20 pCi/liter;
Iodine-131, Cesium-137, Barium-140	4–10 pCi/liter for levels <100 pCi/liter; 4–10% for levels ≧ 100 pCi/liter.

For iodine-131, cesium-137, and barium-140, there is one exception for these precision error ranges: 25 pCi/liter at levels <100 pCi/liter for Colorado. This is reflected in the practical reporting level for the Colorado milk network.

Federal Radiation Council guidance applicable to milk surveillance

In order to place the U.S. data on radioactivity in milk presented in *Radiation Data and Reports* in perspective, a summary of the guidance provided by the Federal Radiation Council for specific environmental conditions was presented in the February 1973 issue of *Radiation Data and Reports.*

Data reporting format

Table 2 presents the integrated results of the international, national, and State networks discussed earlier. Column 1 lists all the stations which are routinely reported in *Radiation Data and Reports.* The relationship between the

Table 2. Concentrations of radionuclides in milk for December 1972 and 12-month period January 1972 through December 1972

Sampling location		Type of sample [a]	Radionuclide concentration (pCi/liter)			
			Strontium-90		Cesium-137	
			Monthly average [b]	12-month average	Monthly average [b]	12-month average
UNITED STATES:						
Ala:	Montgomery [c]	P	NA	6	12	6
Alaska:	Palmer [c]	P	5	5	0	6
Ariz:	Phoenix [c]	P	NA	0	0	0
Ark:	Little Rock [c]	P	7	11	0	4
Calif:	Sacramento [c]	P	NA	1	0	0
	San Francisco [c]	P	NA	1	0	0
	Del Norte	P	10	12	0	9
	Fresno	P	0	1	0	4
	Humboldt	P	3	4	0	6
	Los Angeles	P	0	2	0	3
	Mendocino	P	2	5	15	6
	Sacramento	P	0	2	0	5
	San Diego	P	0	1	0	4
	Santa Clara	P	0	1	0	4
	Shasta	P	0	2	0	6
	Sonoma	P	2	2	0	5
Colo:	Denver [c]	P	NA	4	0	2
	East	R	NS	NA	NS	0
	Northeast	R	NS	NA	NS	1
	Northwest	R	NS	NA	NS	0
	South Central	R	NS	NA	NS	NS
	Southeast	R	NS	NA	NS	0
	Southwest	R	NS	NA	0 [d]	0
	West	R	NS	NA	NS	4
Conn:	Hartford [c]	P	NA	5	18	8
	Central	P	6	7	14	13
Del:	Wilmington [c]	P	NA	9	0	8
D.C:	Washington [c]	P	NA	7	0	6
Fla:	Tampa [c]	P	3	5	27	35
	Central	R	6	5	30	41
	North	R	8	6	15	16
	Northeast	R	7	5	51	33
	Southeast	R	5	5	48	53
	Tampa Bay area	F	4	5	34	36
	West	R	10	8	15	15
Ga:	Atlanta [c]	P	NS	9	NS	10
Hawaii:	Honolulu [c]	P	0	2	0	1
Idaho:	Idaho Falls [c]	P	0	4	0	0
Ill:	Chicago [c]	P	5	5	0	9
Ind:	Indianapolis [c]	P	NA	6	0	3
	Central	P	10	7	0	10
	Northeast	P	6	6	10	10
	Northwest	P	8	8	0	10
	Southeast	P	7	8	0	10
	Southwest	P	7	7	10	10
Iowa:	Des Moines [c]	P	NA	4	0	0
	Iowa City	P	4	7	0	7
	Des Moines	P	4	6	0 (3)	5
	Little Cedar	P	7	7	0	8
	Le Mars	P	3	3	0	0
Kans:	Wichita [c]	P	NA	7	0	0
	Coffeyville	P	NA	8	0	9
	Dodge City	P	NA	5	0	7
	Falls City, Nebr	R	NA	3	NS	8
	Hays	P	NA	9	0	7
	Kansas City	P	NA	8	3	9
	Topeka	P	NA	7	0	8
	Wichita	P	NA	8	2	5
Ky:	Louisville [c]	P	NA	7	0	6
La:	New Orleans [c]	P	11	12	0	3
Maine:	Portland [c]	P	NA	6	17	23
Md:	Baltimore [c]	P	NA	7	0	5
Mass:	Boston [c]	P	7	7	14	14
Mich:	Detroit [c]	P	NA	6	0	8
	Grand Rapids [c]	P	NA	8	0	6
	Bay City	P	0	4	0 (2)	8
	Charlevoix	P	5	5	0 (5)	10
	Detroit	P	3	4	0	7
	Grand Rapids	P	3	4	0	7
	Lansing	P	4	4	0 (2)	9
	Marquette	P	5	5	0 (2)	18
	Monroe	P	0	2	0	4
	South Haven	P	6	5	0 (4)	8
Minn:	Minneapolis [c]	P	NA	7	11	16
	Bemidji	P	6	7	10	18
	Duluth	P	15	15	16	27
	Fergus Falls	P	6	7	10	20
	Little Falls	P	14	17	11	39
	Mankato	P	5	5	11	11
	Marshall	P	NS	5	NS	12

See footnotes at end of table.

Table 2. Concentrations of radionuclides in milk for December 1972 and 12-month period January 1972 through December 1972—continued

Sampling location		Type of sample [a]	Radionuclide concentration (pCi/liter)			
			Strontium-90		Cesium-137	
			Monthly average [b]	12-month average	Monthly average [b]	12-month average
UNITED STATES—Continued						
Minn:	Minneapolis	P	7	10	8	14
	Rochester	P	6	7	8	11
Miss:	Jackson [c]	P	NA	9	0	7
Mo:	Kansas City [c]	P	NA	5	0	1
	St. Louis [c]	P	NA	6	0	3
Mont:	Helena [c]	P	NA	4	0	3
Nebr:	Omaha [c]	P	NA	6	0	1
Nev:	Las Vegas [c]	P	NA	1	0	0
N.H:	Manchester [c]	P	NA	8	11	16
N.J:	Trenton [c]	P	NA	7	15	6
N. Mex:	Albuquerque [c]	P	NA	1	0	0
N.Y:	Buffalo [c]	P	3	5	0	4
	New York City [c]	P	NA	8	0	8
	Syracuse [c]	P	NA	6	0	7
	Albany	P	0	4	0	0
	Buffalo	P	0	6	0	0
	Massena	P	4	8	0	0
	New York City	P	0	7	0	0
	Syracuse	P	0	5	0	0
N.C:	Charlotte [c]	P	NA	9	0	6
N. Dak:	Minot [c]	P	NA	9	0	6
Ohio:	Cincinnati [c]	P	NA	6	0	4
	Cleveland [c]	P	NA	7	0	7
Okla:	Oklahoma City [c]	P	NA	5	0	2
Oreg:	Portland [c]	P	4	5	0	3
	Baker	P	NA		NA	
	Coos Bay	P	NA		NA	
	Eugene	P	NA		NA	
	Medford	P	NA		NA	
	Portland composite	P	NA		NA	
	Portland local	P	NA		NA	
	Redmond	P	NA		NA	
	Tillamook	P	NA		NA	
Pa:	Philadelphia [c]	P	NA	6	0	3
	Pittsburgh [c]	P	NA	9	15	8
	Dauphin	P	NA		NA	
	Erie	P	NA		NA	
	Philadelphia	P	NA		NA	
	Pittsburgh	P	NA		NA	
R.I:	Providence [c]	P	NA	6	0	9
S.C:	Charleston [c]	P	7	8	0	13
S. Dak:	Rapid City [c]	P	NA	7	0	2
Tenn:	Chattanooga [c]	P	NA	8	0	7
	Memphis [c]	P	NA	7	0	1
	Chattanooga	P	NA	10	0	10
	Clinton	R	NA	10	0	12
	Fayetteville	R	NA	10	6 (2)	6
	Kingston	R	NA	10	8 (2)	7
	Knoxville	P	NA	8	11 (2)	8
	Lawrenceburg	R	NS	1	NS	2
	Nashville	P	NA	8	0	9
	Pulaski	R	NA	7	6 (2)	7
	Sequoyah	R	NS	7	NS	17
Tex:	Austin [c]	P	NA	2	0	0
	Dallas [c]	P	NA	6	0	0
	Amarillo	P	NA		NA	
	Corpus Christi	R	NA		NA	
	El Paso	R	NA		NA	
	Fort Worth	R	NA		NA	
	Harlingen	R	NA		NA	
	Houston	R	NA		NA	
	Lubbock	R	NA		NA	
	Midland	R	NA		NA	
	San Antonio	R	NA		NA	
	Texarkana	R	NA		NA	
	Uvalde	R	NA		NA	
	Wichita Falls	R	NA		NA	
Utah:	Salt Lake City [c]	P	3	3	0	3
Vt:	Burlington [c]	P	NA	6	15	12
Va:	Norfolk [c]	P	NA	6	0	7
Wash:	Seattle [c]	P	NA	3	0	2
	Spokane [c]	P	NA	4	0	5
	Benton County	R	NS	1	NS	0
	Franklin County	R	0	1	0	0
	Longview	R	0	4	0	2
	Sandpoint, Idaho	R	5	9	0	10
	Skagit County	R	6	7	0	4
W. Va:	Charleston [c]	P	NA	8	0	5
Wisc:	Milwaukee [c]	P	NS	5	NS	7
Wyo:	Laramie [c]	P	NA	3	0	0

See footnotes at end of table.

Table 2. Concentrations of radionuclides in milk for December 1972 and 12-month period January 1972 through December 1972—continued

Sampling location	Type of sample [a]	Radionuclide concentration (pCi/liter)			
		Strontium-90		Cesium-137	
		Monthly average [b]	12-month average	Monthly average [b]	12-month average
CANADA:					
Alberta: Calgary	P	6	6	10	16
Edmonton	P	6	7	20	25
British Columbia: Vancouver	P	6	7	11	20
Manitoba: Winnipeg	P	5	6	13	17
New Brunswick: Moncton	P	7		7	8
Newfoundland: St. John's	P	15	19	17	24
Nova Scotia: Halifax	P	7	8	11	16
Ontario: Ottawa	P	6	6	11	10
Sault Ste. Marie	P	10	11	12	22
Thunder Bay	P	9	10	12	21
Toronto	P	3	3	10	9
Windsor	P	3	3	5	7
Quebec: Montreal	P	6	7	7	11
Quebec	P	8	9	16	21
Saskatchewan: Regina	P	5	6	11	13
Saskatoon	P	7	7	11	13
CENTRAL AND SOUTH AMERICA:					
Canal Zone: Cristobal [c]	P	NA	1	0	9
Chile: Santiago	P	0	1	0	1
Colombia: Bogota	P	2	1	0	0
Ecuador: Guayaquil	P	0	0	0	0
Jamaica: Kingston	P	NS	3	NS	45
Puerto Rico: San Juan [c]	P	NA	1	0	3
Venezuela: Caracas	P	0	0	0	0
PMN network average [e]		5	6	2	6

[a] P, pasteurized milk.
R, raw milk.

[b] When an individual sampling result was equal to or less than the practical reporting level, a value of "0" was used for averaging. Monthly averages less than the practical reporting level reflect the fact that some but not all of the individual samples making up the average contained levels greater than the practical reporting level. When more than one analysis was made in a monthly period, the number of samples in the monthly average is given in parentheses.

[c] Pasteurized Milk Network station. All other sampling locations are part of the State or National network.

[d] The practical reporting level for this network differs from the general ones given in the text. Sampling results for these networks were equal to or less than the following practical reporting levels:
Cesium-137: Colorado—25 pCi/liter; Oregon—15 pCi/liter.

[e] This entry gives the average radionuclide concentrations for the Pasteurized Milk Network stations denoted by footnote [c].
NA, no analysis.
NS, no sample collected.

PMN stations and the State stations is shown in figure 2. The first column in table 2 under each of the reported radionuclides gives the monthly average for the station and the number of samples analyzed in that month in parentheses. When an individual sampling result is equal to or below the practical reporting level for the radionuclide, a value of zero is used for averaging. Monthly averages are calculated using the above convention. Averages which are equal to or less than the practical reporting levels reflect the presence of radioactivity in some of the individual samples greater than the practical reporting level.

The second column under each of the radionuclides reported gives the 12-month average for the station as calculated from the preceding 12 monthly averages, giving each monthly average equal weight. Since the daily intake of radioactivity by exposed population groups, averaged over a year, constitutes an appropriate criterion for the case where the FRC radiation protection guides apply, the 12-month average serves as a basis for comparison.

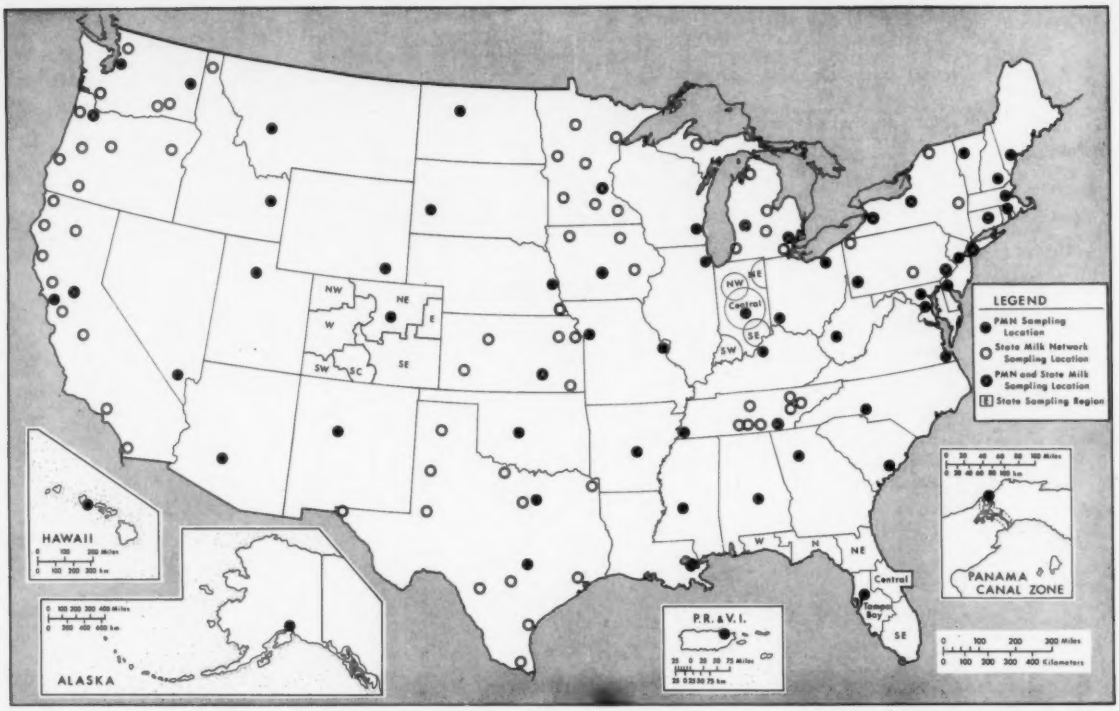

Figure 2. State and PMN milk sampling stations in the United States

Discussion of current data

In table 2, surveillance results are given for strontium-90 and cesium-137 for December 1972 and the 12-month period, January 1972 to December 1972. Except where noted, the monthly average represents a single sample for the sampling station. Strontium-89, iodine-131, and barium-140 data have been omitted from table 2 since levels at all of the stations for December 1972 were below the respective practical reporting levels.

Strontium-90 monthly averages ranged from 0 to 15 pCi/liter in the United States for December 1972, and the highest 12-month average was 17 pCi/liter (Little Falls, Minn.) representing 8.5 percent of the Federal Radiation Council radiation protection guide. Cesium-137 monthly averages ranged from 0 to 51 pCi/liter in the United States for December 1972, and the highest 12-month average was 53 pCi/liter (Southeast Florida) representing 1.5 percent of the value derived from the recommendations given in the Federal Radiation Council Report. Of particular interest are the consistently higher cesium-137 levels that have been observed in Florida (*8*) and Jamaica.

Acknowledgement

Appreciation is expressed to the personnel of the following agencies who provide data from their milk surveillance networks:

Bureau of Radiological Health
Environmental Health & Consumer Protection Program
California Department of Public Health

Radiation Protection Division
Canadian Department of National Health and Welfare

Radiological Health Section
Division of Occupational and Radiological Health
Colorado Department of Health

Radiological Health Services
Division of Medical Services
Connecticut State Department of Health

Radiological and Occupational Health Section
Department of Health and Rehabilitative Services
State of Florida

Bureau of Environmental Sanitation
Division of Sanitary Engineering
Indiana State Board of Health

Division of Radiological Health
Environmental Engineering Services
Iowa State Department of Health

Radiation Control Section
Environmental Health Division
Kansas State Department of Health

Radiological Health Services
Division of Occupational Health
Michigan Department of Health

Radiation Control Section
Division of Environmental Health
State of Minnesota Department of Health

Bureau of Radiological Pollution Control
New York State Department of Environmental Conservation

Environmental Radiation Surveillance Program
Division of Sanitation and Engineering
Oregon State Board of Health

Radiological Health Section
Bureau of Environmental Health
Pennsylvania Department of Public Health

Radiological Health Services
Division of Preventable Diseases
Tennessee Department of Public Health

Division of Occupational Health
Environmental Health Services
Texas State Department of Health

Radiation Control Section
Division of Health
Washington Department of Social and Health Services

REFERENCES

(*1*) CAMPBELL, J. E., G. K. MURTHY, A. S. GOLDIN, H. B. ROBINSON, C. P. STRAUB, F. J. WEBER and K. H. LEWIS. The occurrence of strontium-90, iodine-131, and other radionuclides in milk, May 1957 through April 1958. Amer J Pub Health 49:225 (February 1969).

(*2*) U.S. ATOMIC ENERGY COMMISSION, DIVISION OF ISOTOPES DEVELOPMENT. Chart of the Nuclides, Tenth Edition revised to December 1968. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

(*3*) NATIONAL CENTER FOR RADIOLOGICAL HEALTH. Section I. Milk Surveillance. Radiol Health Data Rep 9:730–746 (December 1968).

(*4*) ROSENSTEIN, M. and A. S. GOLDIN. Statistical technics for quality control of environmental radioassay. Health Lab Sci 2:93 (April 1965).

(*5*) KNOWLES, F. Interlaboratory study of iodine-131, cesium-137, strontium-89 and strontium-90 measurements in milk, July 1971, Technical experiment 71–MKAQ–1. Analytical Quality Control Service, Office of Radiation Programs, EPA, Washington, D.C. 20460 (December 1971).

(*6*) ROBINSON, P. B. A comparison of results between the Public Health Service Raw Milk and Pasteurized Milk Networks for January 1964 through June 1966. Radiol Health Data Rep 9:475–488 (September 1968).

(*7*) PORTER, C. R., C. R. PHILLIPS, M. W. CARTER and B. KAHN. The cause of relatively high cesium-137 concentrations in Tampa, Florida, milk. Radioecological Concentration Processes, Proceedings of an International Symposium held in Stockholm, April 25–29, 1966. Pergamon Press, New York, N.Y. (1966) pp. 95–101.

Milk Surveillance Programs, October 1972

National Environmental Research Center—Las Vegas, Environmental Protection Agency

The Milk Surveillance Network,[1] operated by the National Environmental Research Center—Las Vegas (NERC–LV), consists of 32 regular and 5 alternate sampling locations (figure 1) situated in the offsite area surrounding the Nevada Test Site (NTS). This routine network is operated in support of the nuclear testing programs sponsored by the U.S. Atomic Energy Commission (AEC) and by the Space Nuclear Systems Office, National Aeronautical and Space Administration.

In the event of a release of radioactivity from the NTS, special sampling within the affected

[1] This network is operated under a Memorandum of Understanding (No. AT (26–1)–539) with the Nevada Operations Office, AEC, Las Vegas, Nev.

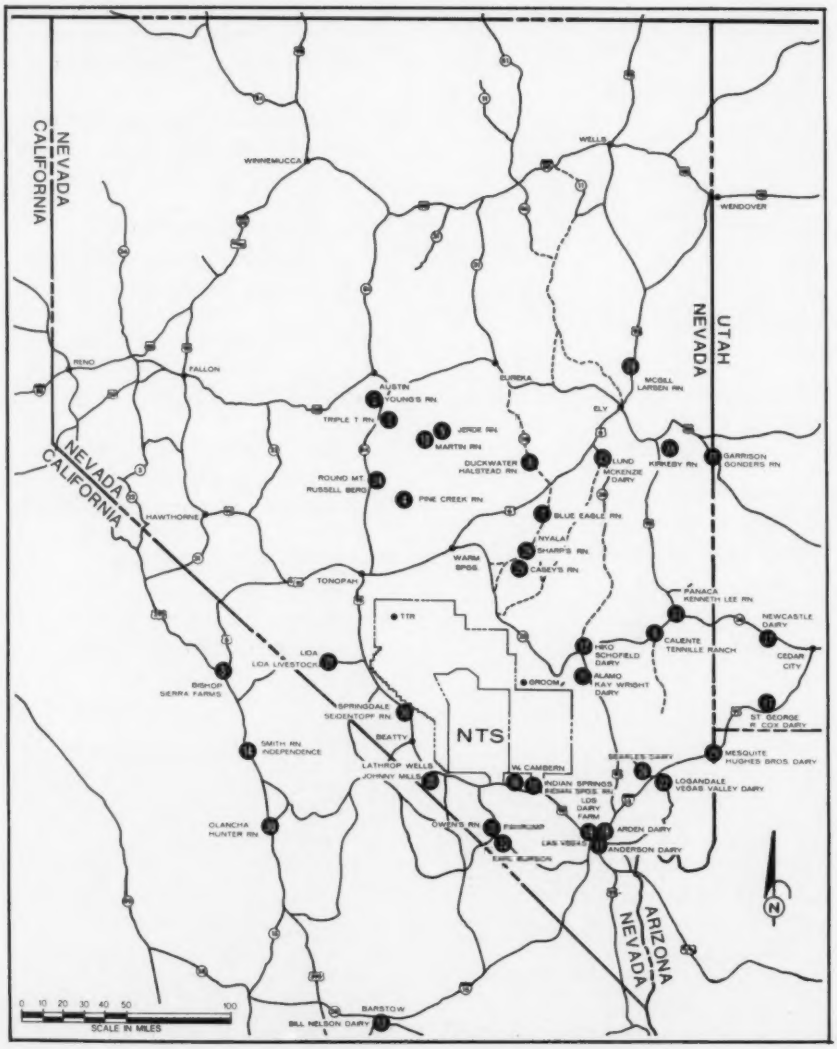

Figure 1. NERC-LV Milk Surveillance Network

Table 1. Milk surveillance results, October 1972

Location	Map number	Date collected (October 1972)	Sample type [a]	Radionuclide concentrations [b] (pCi/liter)			
				^{137}Cs	^{89}Sr	^{90}Sr	^{3}H
California:							
Bishop:							
Sierra Farms	5	12	11	<10	<3	2±2	NA
Hinkley:							
Bill Nelson Dairy	13	10	12	<10	<2	<1	NA
Independence:							
Smith Ranch [c]	14	12	13	<100	<2	2±1	NA
Nevada:							
Alamo:							
Williams Dairy	1	5	12	<10	<2	4±2	NA
Austin:							
Young's Ranch	3	3	13	<10	<2	5±2	NA
Belmont:							
Pine Creek Ranch [c]	4	2	13	<100	<3	4±2	NA
Currant:							
Blue Eagle Ranch	7	4	13	<10	<2	1±1	NA
Duckwater:							
Halstead Ranch [c]	8	4	13	<100	<2	<1	NA
Eureka:							
Martin Ranch	10	12	13	10	<4	9±3	NA
Hiko:							
Schofield Dairy	12	2	12	<10	<2	<1	<200
Indian Springs:							
Indian Springs Ranch	15	3	13	<10	<2	<1	NA
Las Vegas:							
Anderson Dairy	17	11	11	<10	<2	<1	NA
Arden Dairy	18	11	11	<10	<2	<1	NA
LDS Dairy Farms	19	10	12	<10	<2	1±1	<200
Lathrop Wells:							
Mills Ranch	20	5	13	<10	<2	<1	NA
Lida:							
Lida Livestock Company	21	1	13	<10	<2	<2	NA
Logandale:							
Vegas Valley Dairy	22	2	12	<10	<2	<1	NA
Lund:							
McKenzie Dairy	23	3	12	<10	<2	2±2	<200
McGill:							
Larsen Ranch	24	3	13	<10	<1	<1	NA
Mesquite:							
Hughes Bros. Dairy	25	2	12	<10	<1	<1	<200
Moapa:							
Searles Dairy [c]	26	2	12	<100	<2	<1	NA
Nyala:							
Sharp's Ranch	28	4	13	<10	<2	3±1	<200
Pahrump:							
Owens Ranch	31	3	13	<10	<1	<1	NA
Panaca:							
Kenneth Lee Ranch	33	3	13	<10	<2	3±2	NA
Shoshone:							
Kirkeby Ranch	35	2	13	<10	<2	3±2	NA
Springdale:							
Seidentopf Ranch	36	4	13	<10	<2	<1	NA
Utah:							
Garrison:							
Gonder's Ranch	11	2	13	<10	<3	2±1	NA
New castle:							
Newcastle Dairy	27	4	12	<10	<2	3±1	NA
St. George:							
R. Cox Diary	37	2	12	<10	<2	2±1	NA

[a] 11, pasteurized milk.
12, raw milk from Grade A producer(s).
13, raw milk from family cow(s).
[b] Two-sigma counting error provided when available.
[c] Small sample size increased minimum detectable activity.
NA, not analyzed.

area is conducted to determine radionuclide concentrations and to take protective action, if required. Additional sampling networks are operated in support of AEC operations in areas other than the NTS when requested. A complete description of sampling and analytical

procedures was included with the milk results reported in the December 1972 issue of *Radiation Data and Reports.*

Results

The analytical results of all milk samples collected in October 1972 by NERC-LV surveillance programs are listed in table 1. With the exception of cesium-137 at levels near the minimum detectable activity (MDA) of 10 pCi/liter, no gamma-emitting fission products were detected in any of the samples by gamma spectroscopy analysis. Levels of tritium, strontium-89, and strontium-90 near the MDA's for these radionuclides (~ 200 pCi/liter, 2 pCi/liter, and 1 pCi/liter, respectively) were also measured by radiochemistry analyses. Copies of these results were distributed to EPA Regional Offices and appropriate State agencies prior to publication.

Food and Diet Surveillance

Efforts are being made by various Federal and State agencies to estimate the dietary intake of selected radionuclides on a continuing basis. These estimates, along with the guidance developed by the Federal Radiation Council, provide a basis for evaluating the significance of radioactivity in foods and diet.

Networks presently in operation and reported routinely include those listed below. These networks provide data useful for developing estimates of nationwide dietary intake of radionuclides. Programs reported in *Radiation Data and Reports* are as follows:

Program	Period reported	Issue
California Diet Study	January–June 1971	December 1972
Carbon-14 in Total Diet and Milk	July–December 1971	May 1972
Connecticut Standard Diet	January–December 1971	December 1972
	This program has been discontinued	
Institutional Total Diet	October–December 1971 and 1971 Annual Summary	June 1972
Radiostrontium in Milk	January–December 1971	November 1972
Strontium-90 in Tri-City Diets	January–December 1971	December 1972

SECTION II. WATER

The Environmental Protection Agency and other Federal, State, and local agencies operate extensive water quality sampling and analysis programs for surface, ground, and treated water. Most of these programs include determinations of gross beta and gross alpha radioactivity and specific radionuclides.

Although the determination of the total radionuclide intake from all sources is of primary importance, a measure of the public health importance of radioactivity levels in water can be obtained by comparison of the observed values with the Public Health Service Drinking Water Standards (*1*). These standards, based on consideration of Federal Radiation Council (FRC) recommendations (*2–4*) set the limits for approval of a drinking water supply containing radium-226 and strontium-90 at 3 pCi/liter and 10 pCi/liter, respectively. Higher concentrations may be acceptable if the total intake of radioactivity from all sources remains within the guides recommended by FRC for control action. In the known absence [1] of strontium-90 and alpha-particle emitters, the limit is 1,000 pCi/liter gross beta radioactivity, except when additional analysis indicates that concentrations of radionuclides are not likely to cause exposures greater than the limits indicated by the Radiation Protection Guides. Surveillance data from a number of Federal and State programs are published periodically to show current and long-range trends. Water sampling activities reported in *Radiation Data and Reports* are listed below.

[1] Absence is taken to mean a negligibly small fraction of the specific limits of 3 pCi/liter and 10 pCi/liter for unidentified alpha-particle emitters and strontium-90, respectively.

Water sampling program	Period reported	Issue
California	January–December 1970	June 1972
Colorado River Basin	1968	March 1972
Community Water Supply Study	1969	September 1972
Florida	1969	January 1972
Interstate Carrier Drinking Water	1971	May 1972
Kansas	January–December 1971	February 1973
Michigan	January–June 1970	November 1971
Minnesota	July 1970–June 1971	November 1972
New York	July–December 1970 and January–June 1971	May 1972
North Carolina	1968–1970	September 1972
Radiostrontium in Tap Water	July–December 1971	November 1972
Tritium Surveillance System	July–September 1972	February 1973
Washington	July 1969–June 1970	March 1972
Water Surveillance Programs, *NERC–LV*	July–September 1972	March 1973

REFERENCES

(*1*) U.S. PUBLIC HEALTH SERVICE. Drinking water standards, revised 1962, PHS Publication No. 956. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (March 1963).

(*2*) FEDERAL RADIATION COUNCIL. Radiation Protection Guidance for Federal Agencies. Memorandum for the President, September 1961. Reprint from the Federal Register of September 26, 1961.

(*3*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 1. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 1960).

(*4*) FEDERAL RADIATION COUNCIL. Background material for the develoment of Radiation Protection Standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

Gross Radioactivity in Surface Waters of the United States October-November 1972

Office of Water Planning and Standards
U.S. Environmental Protection Agency

The monitoring of gross radioactivity in surface waters of the United States was initiated in 1957 as part of the Water Pollution Surveillance System (formerly National Water Quality Network) of the U.S. Public Health Service. Currently, the program is operated by the U.S. Environmental Protection Agency, Office of Water Planning and Standards. Regional offices of the Environmental Protection Agency are responsible for the collection and retrieval system. Radioactivity analyses was performed in the centralized laboratories of the Office of Water Planning and Standards (Cincinnati, Ohio).

The regular reporting of gross radioactivity data in *Radiological Health Data and Reports* was terminated with the publication of data for October 1968 (April 1969 issue). With the publication of data for January 1971, this activity was resumed as a monthly report series. The unpublished data for the time interval of November 1968 through December 1970 will be the subject of a future summary article.

Tables 1 and 2 present the gross alpha and beta radioactivity results for samples collected from rivers during October and September 1972. The analytical procedures used for determining gross alpha and beta radioactivity are

Table 1. Gross radioactivity in U.S. surface waters, October 1972

River and station	Number of grab samples	Gross alpha radioactivity (pCi/liter)		Gross beta radioactivity (pCi/liter)	
		Suspended solids	Dissolved solids	Suspended solids	Dissolved solids
Colorado River:					
Moab, Utah					
Highway bridge	3	2.3	10.5	9	20
		22.1	10.3	50	18
		12.8	20.3	61	56
Above Mill Creek, Utah	3	3.0	10.8	10	13
		5.2	11.1	17	27
		16.9	20.0	49	44
Dolores River:					
Bedrock, Colo	2	7.1	18.3	16	25
		18.4	4.4	123	15
Gateway, Colo	2	18.3	47.7	33	67
		6.2	24.5	19	39
Green River:					
Greendale, Utah	2	.3	3.5	<1	11
LaBarge, Wyo		<.3	.6	<1	5
Ohio River:					
Cincinnati, Ohio	2	.7	<1.0	<1	6
		.4	<.9	<1	6
Roanoke River:					
John Kerr Dam, Va	1	.3	<.6	1	4
San Miguel River:					
Uravan, Colo	2	1.5	5.5	5	16
		7.0	4.3	24	8
Below Uravan, Colo	2	5.5	27.3	13	23
		15.6	7.8	32	10
Naturita, Colo	2	<.3	4.3	2	7
		.4	1.6	2	4
San Juan River:					
Bluff, Ariz	1	17.0	3.2	43	11
St. Lawrence River:					
Massena, N.Y	4	<.3	<.6	<1	5
		<.4	<.5	<1	9
		<.3	<.5	<1	5
		<.3	<.5	<1	5

Table 2. Gross radioactivity in U.S. surface waters, November 1972

River and station	Number of grab samples	Gross alpha radioactivity (pCi/liter)		Gross beta radioactivity (pCi/liter)	
		Suspended solids	Dissolved solids	Suspended solids	Dissolved solids
Roanoke River:					
John Kerr Dam, Va	3	<0.3	<0.3	<1	2
		<.3	<.3	<1	2
		<.3	<.4	<1	2
St. Lawrence River:					
Massena, N.Y	3	<.3	<.5	<1	4
		<.3	<.6	<1	5
		<.3	<.6	<1	6
Susquehanna River:					
Holtwood, Pa	1	<.4	<1.1	1	4

described in the 13th Edition of *Standard Methods for the Examination of Water and Wastewater* (*1*). Results are collected for the date of counting and are not corrected to the date of collection. The sensitivity in counting is that defined by the National Bureau of Standards, Handbook 86 (*2*) and is calculated to be <0.2 pCi/liter for gross alpha radioactivity and <1 pCi/liter for gross beta radioactivity measurements.

REFERENCES

(*1*) AMERICAN PUBLIC HEALTH ASSOCIATION; AMERICAN WATER WORKS ASSOCIATION AND WATER POLLUTION CONTROL FEDERATION. Standard methods for the examination of water and wastewater, 13th Edition, New York, N.Y. (1971).

(*2*) U.S. DEPARTMENT OF COMMERCE. Radioactivty, Recommendations of the International Commission on Radiological Units and Measurements (1962), NBS Handbook 86 (November 29, 1963).

Water Surveillance Programs, October 1972

National Environmental Research Center—Las Vegas, Environmental Protection Agency

The Water Surveillance Network,[1] operated by the National Environmental Research Center—Las Vegas (NERC–LV), consists of 90 sampling locations (figures 1 and 2) situated in the offsite area surrounding the Nevada Test Site (NTS). This routine network is operated in support of the nuclear testing programs sponsored by the U.S. Atomic Energy Commission (AEC) and by the Space Nuclear Systems Office, National Aeronautical and Space Administration.

In the event of a release of radioactivity from the NTS, special sampling within the

[1] This network is operated under a Memorandum of Understanding (No. AT(26–1)–539) with the Nevada Operations Office, AEC, Las Vegas, Nev.

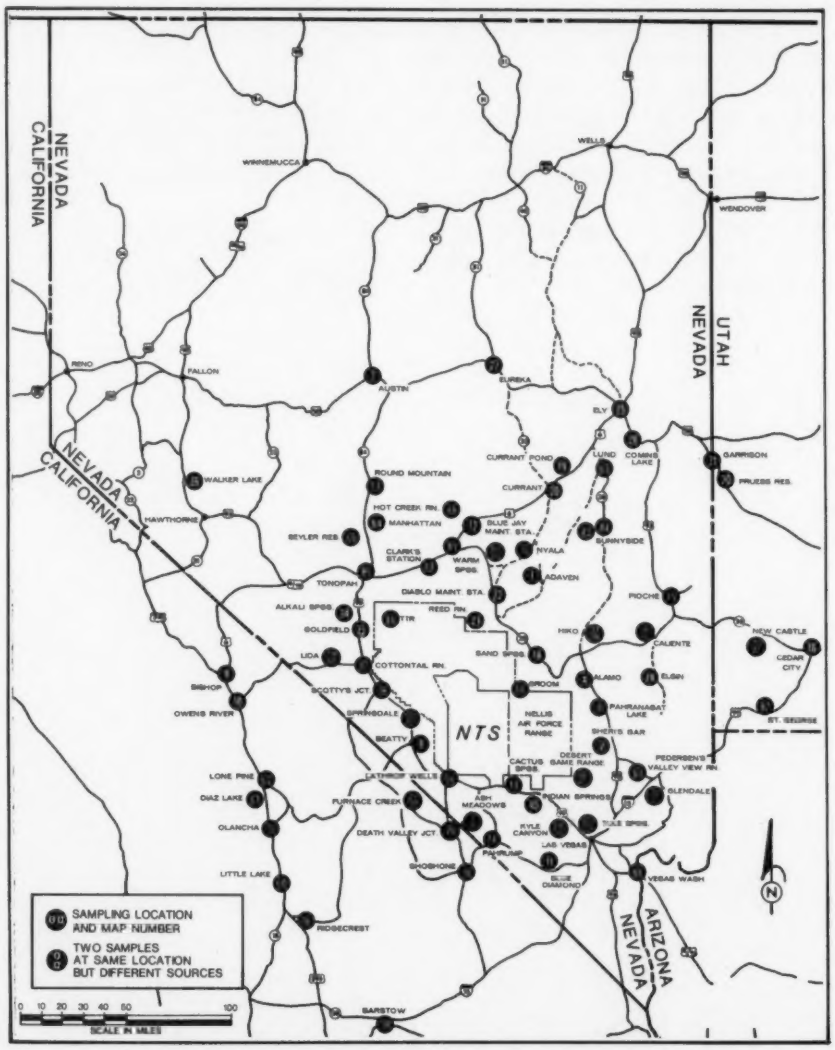

Figure 1. NERC-LV Water Surveillance Network

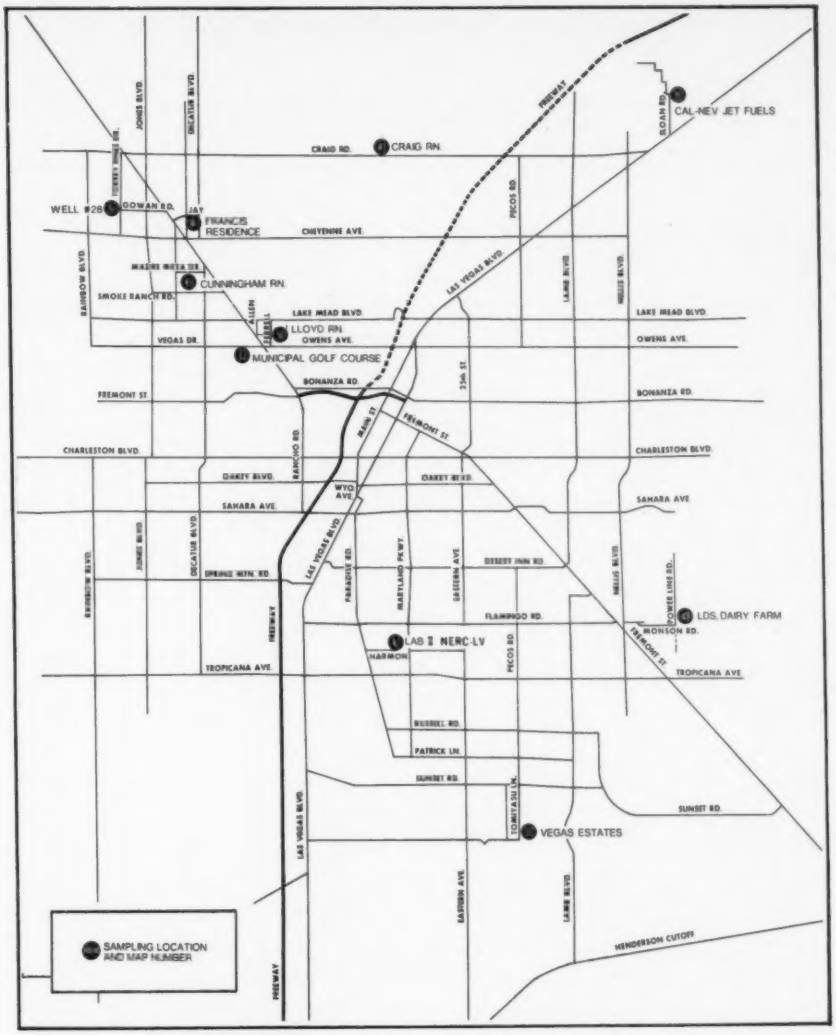

Figure 2. Water Surveillance Network—Las Vegas Valley

affected area is conducted to determine radionuclide concentrations and to take protective action, if required. Other sampling networks are operated in support of AEC operations in areas other than the NTS when requested. A complete description of sampling and routine analytical procedures was included with the water results reported in the November 1972 issue of *Radiation Data and Reports.*

Results

The analytical results of all water samples collected in October 1972 by the NERC–LV Water Surveillance Network are listed in table 1. No gamma-emitting fission products were detected in any of the samples by gamma spectroscopy analysis. The analytical results of samples selected for special analyses will be reported at a later date.

Table 1. NERC-LV water surveillance results, October 1972

Location	Map number	Data collected (1972)	Sample type [b]	Radioactivity concentration [a] (pCi/liter)		
				Gross alpha	Gross beta	Tritium
California:						
Bishop:						
Fish and Game Office	9	12	23	<2.3	<3.7	NA
Owens River, 3 miles east	10	11	22	<3.9	<4.0	NA
Death Valley Junction:						
Lila's Cafe	21	13	23	8±7	9±5	230±220
Furnace Creek:						
Pond	28	13	21	<7.8	7±3	NA
Visitor's Center	29	13	27	<5.4	12±4.5	NA
Hinkley:						
Bill Nelson Diary	39	10	23	<6.5	8±4	NA
Little Lake:						
Little Lake Ranch	60	11	21	10±7.9	23±5.2	NA
Lone Pine:						
Diaz Lake	61	11	21	21±9.4	27±5.3	NA
Forest Service Ranger Station	62	11	23	<3.0	7±4	NA
Olancha:						
Haiwee Reservoir	73	11	21	<3.6	4±4	NA
Ridgecrest:						
City Hall	76	11	23	<5.0	<4.0	NA
Shoshone:						
Chevron Service Station	79	13	27	<6.9	23±5.1	NA
Nevada:						
Adaven:						
Canfield Ranch	1	4	22	10±5	8±4	NA
Alamo:						
Sheri's Bar	2	2	23	<3.4	<3.3	NA
Pahranagat Lake	3	2	21	22±8.6	37±5.1	NA
Williams Dairy	4	2	23	5±5	12±3.9	NA
Ash Meadows:						
Ash Meadows Lodge	5	10	23	<8.4	19±4.2	<230
Ash Meadows Pond	6	10	21	12±8.6	17±4.1	NA
Austin:						
County Courthouse	7	4	27	20±6.3	18±4.0	NA
Beatty:						
Richfield Service Station	8	5	23	12±9.4	16±4.1	<220
Blue Diamond:						
Post Office	11	2	23	<5.6	<3.1	<230
Blue Jay Highway:						
Maintenance Station	12	4	23	9±5	5±3	NA
Cactus Springs:						
Mobile Service Station	13	3	27	<3.6	<3.1	<220
Caliente:						
Agricultural Extension Station	14	4	23	9±5	5±3	NA
Meadow Valley Wash	15	4	22	<6.6	14±3.9	NA
Clark Station:						
Five Mile Ranch	17	4	27	<3.4	5±3	NA
Coyote Summit:						
Sand Spring Well	18	3	23	37±10	26±4.6	NA
Currant:						
Currant Pond	19	4	21	<4.4	6±3	NA
Currant Ranch Cafe	20	4	27	16±7.1	7±3	NA
Diablo Highway:						
Maintenance Station	22	4	23	4±3	8±3	NA
Diablo:						
Reed Ranch	23	3	21	24±8.7	44±5.4	NA
Elgin:						
Water Tower	24	4	23	<6.0	8±3	NA
Ely:						
Chevron Service Station	25	2	24	<3.5	3±3	NA
Comins Lake	26	2	21	<7.8	52±5.7	NA
Eureka:						
Chevron Service Station	27	4	24	<4.5	5±3	NA
Glendale:						
Chevron Service Station	32	2	27	8±7	15±3.9	NA
Muddy River	33	2	22	11±7.4	13±4.1	NA
Goldfield:						
Alkali Springs	34	2	21	<12	6±4	NA
Chevron Service Station	35	2	23	<5.8	<3.2	NA
Hawthorne:						
Walker Lake [c]	36					
Hiko:						
Crystal Springs	37	2	27	7±4	5±3	NA
Schofield Dairy	38	2	23	30±9.1	29±4.8	NA
Indian Springs:						
Chevron Service Station	40	3	23	7±5	5±3	<230
Las Vegas:						
Cal-Nev Jet Fuels	41	10	23	<4.4	<3.1	<220
Craig Ranch Golf Course	42	10	23	8±5	5±3	<220
Cunningham Ranch	43	10	23	<4.1	<3.1	<220
Desert Game Range	44	3	23	<4.1	<3.1	270±220
Desert Game Range Pond	45	3	21	<3.9	<3.1	<220
Francis Residence	46	10	23	<6.9	4±3	<220
Lab II, NERC-LV	47	10	24	<4.6	7±4	930±230

See footnotes at end of table.

Table 1. NERC-LV water surveillance results, October 1972—Continued

Location	Map number	Data collected (1972)	Sample type [b]	Radioactivity concentration [a] (pCi/liter)		
				Gross alpha	Gross beta	Tritium
Nevada:						
Lake Mead Vegas Wash	48	10	21	<7.4	6±3	890±230
LDS Dairy Farm	49	10	23	<11	13±4.1	<220
Lloyd Ranch	50	10	23	<7.1	6±3	<220
L V Water District Well 28	51	10	23	<4.1	<3.1	<230
Municipal Golf Course	52	10	23	<4.2	5±3	<220
Tule Springs	53	3	23	<4.0	<3.1	<220
Tule Springs Pond	54	3	21	<3.6	6±3	NA
Vegas Estates	55	10	23	<7.7	10±4	<220
Lathrop Wells:						
Texaco Service Station	56	4	23	<5.5	4±3	<220
Lida Junction:						
Cottontail Ranch	57	2	23	<6.5	12±3.8	NA
Lida:						
Lida Livestock Company	58	2	27	9±6	<3.1	NA
Pond at storage tank	59	2	21	<4.8	<3.1	NA
Lund:						
Gardner Grocery	63	3	23	<5.0	5±3	NA
Manhattan:						
Country Store	64	4	23	11±7.1	7±3	NA
Seyler Reservoir	65	4	21	5.4	18±4.1	NA
Mercury:						
Groom Lake	66	3	23	4±3	4±3	NA
Moapa:						
Pedersen Valley View Ranch	67	2	27	8±5	7±4	NA
Mt. Charleston:						
Kyle Canyon Fire Station	68	3	27	<4.2	<3.1	240±230
Nyala:						
Sharp's Ranch	72	4	23	<3.1	<3.2	NA
Pahrump:						
Texaco Service Station	74	2	23	<4.2	<3.1	NA
Pioche:						
County Courthouse	75	3	24	<4.0	7±3	NA
Round Mt:						
Mobil Service Station	77	4	27	<3.4	<3.1	NA
Scotty's Junction:						
Chevron Service Station	78	2	23	<7.4	8±4	<220
Springdale:						
Peacock Ranch	80	4	27	<6.4	6±3	<220
Pond	81	4	21	<7.2	14±3.9	NA
Sunnyside:						
Adam McGill Reservoir	83	3	21	9±6	7±3	NA
Wildlife Management Headquarters	84	3	27	<3.8	4±3	NA
Tonopah:						
Jerry's Chevron Station	85	3	23	<4.5	7±3	NA
Tonopah Test Range CP-1	86	3	23	<5.4	6±3	NA
Warm Springs:						
Fallini's Pond	87	4	21	42±15	100±8.0	NA
Hot Creek Ranch	88	4	27	<4.8	11±3.8	NA
Service Station and Cafe	89	3	27	32±11	39±5.3	NA
Twin Springs Ranch	90	4	23	8±5	10±3.7	NA
Utah:						
Cedar City:						
M. D. Baldwin Reservoir	16	3	24	<2.6	<3.3	NA
Garrison:						
Pruess Reservoir [c]	30					
Rowley Grocery	31	2	23	<4.4	3±3	NA
Newcastle:						
Municipal Reservoir	70	3	21	<4.3	7±4	NA
Newcastle Dairy	71	4	24	<4.3	7±4	NA
St. George:						
R. Cox Dairy	82	2	24	<2.1	<3.2	NA

[a] Two-sigma counting error provided when available.
[b] 21—pond, lake, reservoir, stock tank, stock pond.
22—stream, river, creek.
23—well.
24—Multiple supply—mixed water sample consisting of mixed or multiple sources of water, such as well or spring.
27—spring.
[c] Quarterly samples.
NA, not analyzed.

For the purpose of identifying the source of gross radioactivity in all network samples and comparing concentrations with both the AEC Concentration Guides and the PHS Drinking Water Standards, selected samples are being given special analyses at least once a year beginning with samples taken during calendar year 1972. For surface water samples, the special analyses will include strontium-89, strontium-90, plutonium-238, plutonium-239, uranium, and radium-226.

Copies of these results are distributed to EPA Regional Offices and appropriate State agencies prior to publication.

SECTION III. AIR AND DEPOSITION

Radioactivity in Airborne Particulates and Precipitation

Continuous surveillance of radioactivity in air and precipitation provides one of the earliest indications of changes in environmental fission product radioactivity. To date, this surveillance has been confined chiefly to gross beta radioanalysis. Although such data are insufficient to assess total human radiation exposure from fallout, they can be used to determine when to modify monitoring in other phases of the environment.

Surveillance data from a number of programs are published monthly and summarized periodically to show current and long-range trends of atmospheric radioactivity in the Western Hemisphere. These include data from activities of the Environmental Protection Agency, the Canadian Department of National Health and Welfare, and the Pan American Health Organization.

In addition to those programs presented in this issue, the following programs were previously covered in *Radiation Data and Reports.*

Network	Period	Issue
Fallout in the United States and other areas, *HASL*	January–December 1970	December 1971
Mexican air monitoring program	May–August 1972	January 1973
Plutonium in airborne particulates	July–September 1972	March 1973
Surface air sampling program, 80th Meridian Network, *HASL*	January–December 1969	February 1972

1. Radiation Alert Network December 1972

Quality Assurance and Environmental Monitoring Laboratory
Environmental Protection Agency

Surveillance of atmospheric radioactivity in the United States is conducted by the Radiation Alert Network (RAN) which regularly gathers samples at 68 locations distributed throughout the country (figure 1). Most of the stations are operated by State health department personnel.

The station operators perform "field estimates" on the airborne particulate samples at 5 hours after collection, when most of the radon daughter products have decayed, and at 29 hours after collection, when most of the thoron daughter products have decayed. They also perform field estimates on dried precipitation samples and report all results to appropriate Environmental Protection Agency officials by mail or telephone depending on levels found. A compilation of the daily field estimates is available upon request from the Quality Assurance and Environmental Monitoring Laboratory, EPA, Research Triangle Park, N.C. 27711. A detailed description of the sampling and analytical procedures was presented in the March 1968 issue of *Radiological Health Data and Reports*.

Table 1 presents the monthly average gross beta radioactivity in surface air particulates and deposition by precipitation, as measured by the field estimate technique, during December 1972.

Figure 1. Radiation Alert Network sampling stations

Table 1. Gross beta radioactivity in surface air and precipitation, December 1972

Station location		Number of samples	Gross beta radioactivity (5-hour field estimate) (pCi/m³)			Precipitation				
						Number of samples	Total depth (mm)	Field estimation of deposition		
			Maximum	Minimum	Average [a]			Number of samples	Depth (mm)	Total deposition (nCi/m²)
Ala:	Montgomery	18	2	0	0	3	107	3	107	12
Alaska:	Anchorage	2	0	0	0	0				
	Attu Island	31	0	0	0	0				
	Fairbanks	0				0				
	Juneau	0				0				
	Nome	0				0				
	Point Barrow	0				0				
Ariz:	Phoenix	17	12	0	3	0				
Ark:	Little Rock	4	0	0	0	0				
Calif:	Berkeley	19	1	0	0	5	58	5	58	0
	Los Angeles	19	2	0	1	0				
C.Z:	Ancon	14	0	0	0	0				
Colo:	Denver	17	1	0	0	2	26	[b]		
Conn:	Hartford	18	0	0	0	9	143	9	143	0
Del:	Dover	16	0	0	0	0				
D.C:	Washington	12	0	0	0	0				
Fla:	Jacksonville	16	1	0	0	6	105	6	105	2
	Miami	0				0				
Ga:	Atlanta	3	1	0	0	0				
Guam:	Agana	0				0				
Hawaii:	Honolulu	18	1	0	0	0		[b]		
Idaho:	Boise	18	3	0	0	3	56	3	56	0
Ill:	Springfield	3	0	0	0	0				
Ind:	Indianapolis	18	1	0	0	0				
Iowa:	Iowa City	19	1	0	0	3	41	3	41	3
Kans:	Topeka	19	2	0	1	3	19	3	19	0
Ky:	Frankfort	11	1	0	0	0				
La:	New Orleans	17	1	0	0	6	150	[b]		
Maine:	Augusta	19	0	0	0	11	116	11	116	0
Md:	Baltimore	20	1	0	0	9	73	9	73	0
Mass:	Lawrence	20	0	0	0	7	126	7	126	0
	Winchester	17	1	0	0	7	155	7	155	0
Mich:	Lansing	19	0	0	0	0				
Minn:	Minneapolis	20	2	0	1	5	9	5	9	3
Miss:	Jackson	12	1	0	0	5	221	5	221	0
Mo:	Jefferson City	16	1	0	0	5	10	5	10	0
Mont:	Helena	15	1	0	0	0				
Nebr:	Lincoln	18	3	0	1	2	15	2	15	1
Nev:	Las Vegas	18	5	0	1	0				
N.H:	Concord	0				0				
N.J:	Trenton	20	1	0	0	12	144	12	144	4
N. Mex:	Santa Fe	13	1	0	0	0				
N.Y:	Albany	18	2	0	1	0				
	Buffalo	20	0	0	0	0				
	New York City	0				0				
N.C:	Gastonia	17	4	1	1	3	51	[b]		
N. Dak:	Bismarck	19	2	0	1	3	6	3	6	1
Ohio:	Cincinnati	0				0				
	Columbus	2	0	0	0	0				
	Painesville	19	0	0	0	10	72	10	72	21
Okla:	Oklahoma City	3	2	0	1	0				
Oreg:	Portland	20	0	0	0	8	184	8	184	10
Pa:	Harrisburg	19	1	0	0	1	15	1	15	2
P.R:	San Juan	0				0				
R.I:	Providence	15	0	0	0	0				
S.C:	Columbia	8	1	0	1	4	128	4	128	2
S. Dak:	Pierre	14	2	1	1	0				
Tenn:	Nashville	15	1	0	0	9	145	9	145	13
Tex:	Austin	13	7	1	2	2	29	[b]		
	El Paso	19	5	1	2	0				
Utah:	Salt Lake City	27	1	0	0	8	24	8	24	4
Vt:	Barre	19	0	0	0	9	96	9	96	9
Va:	Richmond	19	0	0	0	4	216	4	216	40
Wash:	Seattle	9	0	0	0	6	141	[b]		
	Spokane	18	1	0	0	0				
W. Va:	Charleston	17	1	0	0	12	120	12	120	12
Wisc:	Madison	17	0	0	0	6	34	6	34	2
Wyo:	Cheyenne	11	1	0	0	0				
Network summary		914	12	0	1	188	105	6	90	5

[a] The monthly average is calculated by weighting the field estimates of individual air samples with length of sampling period.
[b] This station is part of the tritium surveillance system. No gross beta measurements are done.

2. Canadian Air and Precipitation Monitoring Program,[1] December 1972

Radiation Protection Division
Department of National Health and Welfare

The Radiation Protection Division of the Canadian Department of National Health and Welfare monitors surface air and precipitation in connection with its Radioactive Fallout Study Program. Twenty-four collection stations are located at airports (figure 2), where the sampling equipment is operated by personnel from the Meteorological Services Branch of the Department of Transport. Detailed discussions of the sampling procedures, methods of analysis, and interpretation of results of the radioactive fallout program are contained in reports of the Department of National Health and Welfare (*1–5*).

A summary of the sampling procedures and methods of analysis was presented in the May 1969 issue of *Radiological Health Data and Reports*.

[1] Prepared from information and data obtained from the Canadian Department of National Health and Welfare, Ottawa, Canada.

Surface air and precipitation data for December 1972 are presented in table 2.

Table 2. Canadian gross beta radioactivity in surface air and precipitation, December 1972

Station	Number of samples	Air surveillance gross beta radioactivity (pCi/m³)			Precipitation measurements	
		Maximum	Minimum	Average	Average concentration (pCi/liter)	Total deposition (nCi/m²)
Calgary	4	0.0	0.0	0.0	28	1.0
Coral Harbour	1	.0	.0	.0	159	.2
Edmonton	4	.0	.0	.0	9	.3
Ft. Churchill	4	.0	.0	.0	19	.1
Fredericton	4	.0	.0	.0	5	1.0
Goose Bay	4	.0	.0	.0	10	.5
Halifax	4	.0	.0	.0	4	.8
Inuvik	4	.0	.0	.0	8	.3
Montreal	4	.0	.0	.0	7	1.0
Moosonee	4	.0	.0	.0	7	.2
Ottawa	3	.0	.0	.0	4	.5
Quebec	4	.0	.0	.0	3	.4
Regina	4	.1	.0	.0	31	.4
Resolute	4	.0	.0	.0	64	.1
St. John's, Nfld.	4	.0	.0	.0	10	1.2
Saskatoon	3	.0	.0	.0	9	.2
Sault Ste. Marie	4	.1	.0	.0	12	1.0
Thunder Bay	4	.0	.0	.0	8	.3
Toronto	4	.0	.0	.0	4	.5
Vancouver	4	.0	.0	.0	4	1.1
Whitehorse	4	.0	.0	.0	10	.3
Windsor	NS				8	.8
Winnipeg	4	.0	.0	.0	16	.4
Yellowknife	1	.0	.0	.0	20	.2
Network summary	84	0.1	0.0	0.0	19	0.5

NS, no sample.

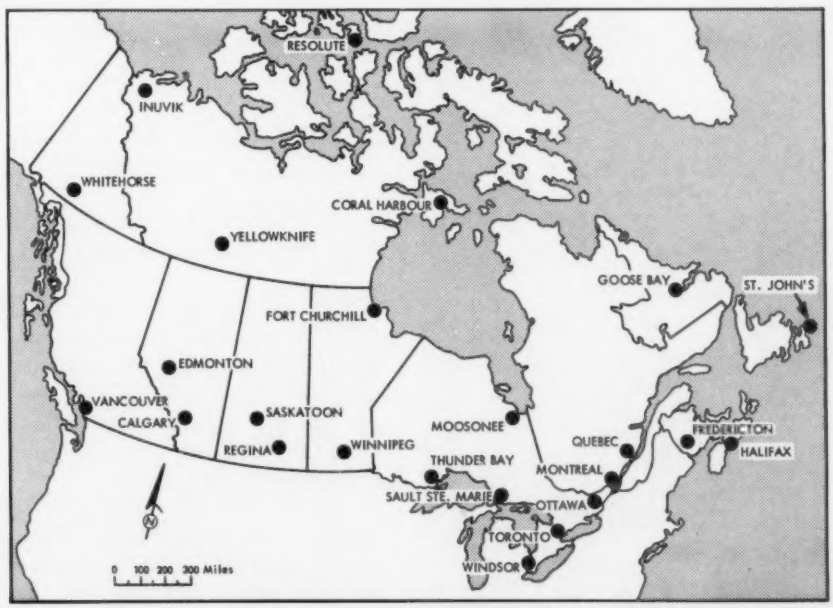

Figure 2. Canadian air and precipitation monitoring program

3. Pan American Air Sampling Program December 1972

Pan American Health Organization and U.S. Environmental Protection Agency

Gross beta radioactivity in air is monitored by countries in the Americas under the auspices of the collaborative program developed by the Pan American Health Organization (PAHO) and the Environmental Protection Agency (EPA) to assist PAHO-member countries in developing radiological health programs.

The air sampling station locations are shown in figure 3. Analytical techniques were described in the March 1968 issue of *Radiological Health Data and Reports*. The December 1972 air monitoring results from the participating countries are given in table 3.

Table 3. Summary of gross beta radioactivity in Pan American surface air, December 1972

Station location		Number of samples	Gross beta radioactivity (pCi/m³)		
			Maximum	Minimum	Average [a]
Argentina:	Buenos Aires	0			
Bolivia:	La Paz	14	0.03	0.00	0.01
Chile:	Santiago	27	.06	.01	.03
Colombia:	Bogota	18	.02	.00	.01
Ecuador:	Cuenca	0			
	Guayaquil	18	.04	.01	.02
	Quito	9	.00	.00	.00
Guyana:	Georgetown	0			
Jamaica:	Kingston	0			
Peru:	Lima	0			
Venezuela:	Caracas	0			
West Indies:	Trinidad	15	.03	.00	.01
Pan American summary		101	0.06	0.00	0.02

[a] The monthly average is calculated by weighting the individual samples with length of sampling period. Values less than 0.005 pCi/m³ are reported and used in averaging as 0.00 pCi/m³.

Figure 3. Pan American Air Sampling Program stations

4. California Air Sampling Program December 1972

Bureau of Radiological Health California State Department of Public Health

The Bureau of Radiological Health of the California State Department of Public Health with the assistance of several cooperating agencies and organizations operates a surveillance system for determining radioactivity in airborne particulates. The air sampling locations are shown in figure 4.

All air samples are sent to the Sanitation and Radiation Laboratory of the State Department of Public Health where they are analyzed for their radioactive content.

Figure 4. California air sampling program stations

Airborne particles are collected by a continuous sampling of air filtered through a 47 millimeter membrane filter, 0.8 micron pore size, using a Gast air pump of about 2 cubic feet per minute capacity, or 81.5 cubic meters per day. Air volumes are measured with a direct reading gas meter. Filters are replaced every 24 hours except on holidays and weekends. The filters are analyzed for gross alpha and beta radioactivity 72 hours after the end of the collection period. The daily samples are then composited into a monthly sample for gamma spectroscopy and an analysis for strontium-89 and strontium-90. Table 4 presents the monthly gross beta radioactivity in air for December 1972. The monthly sample results are presented quarterly.

Table 4. Gross beta radioactivity in California air December 1972

Station location	Number of samples	Gross beta radioactivity (pCi/m³)		
		Maximum	Minimum	Average
Bakersfield	17	1.10	0.03	0.16
Barstow	21	.72	.02	.23
Berkeley	31	.22	.00	.07
Colfax	31	.07	.00	.04
El Centro	29	1.09	.04	.17
Eureka	20	.05	.00	.02
Fresno	29	.51	.03	.10
Los Angeles	29	.26	.00	.09
Redding	28	.08	.01	.04
Sacramento	29	.16	.00	.07
Salinas	29	1.35	.00	.21
San Bernardino	27	.82	.00	.15
San Diego	29	.42	.00	.10
Santa Rosa	30	.17	.00	.06
Summary	379	1.35	0.00	0.11

REFERENCES

(*1*) BIRD, P. M., A. H. BOOTH, and P. G. MAR. Annual report of 1959 on the Radioactive Fallout Study Program, CNHW–RP–3. Department of National Health and Welfare, Ottawa, Canada (May 1960).

(*2*) BIRD, P. M., A. H. BOOTH, and P. G. MAR. Annual report for 1960 on the Radioactive Fallout Study Program, CNHW–RP–4. Department of National Health and Welfare, Ottawa, Canada (December 1961).

(*3*) MAR, P. G. Annual report for 1961 on the Radioactive Fallout Study Program, CNHW–RP–5. Department of National Health and Welfare, Ottawa, Canada (December 1962).

(*4*) BEALE, J. and J. GORDON. The operation of the Radiation Protection Division Air Monitoring Program, RPD–11. Department of National Health and Welfare, Ottawa, Canada (July 1962).

(*5*) BOOTH, A. H. The calculation of permissible levels of fallout in air and water and their use in assessing the significance of 1961 levels in Canada, RPD–21. Department of National Health and Welfare, Ottawa, Canada (August 1962).

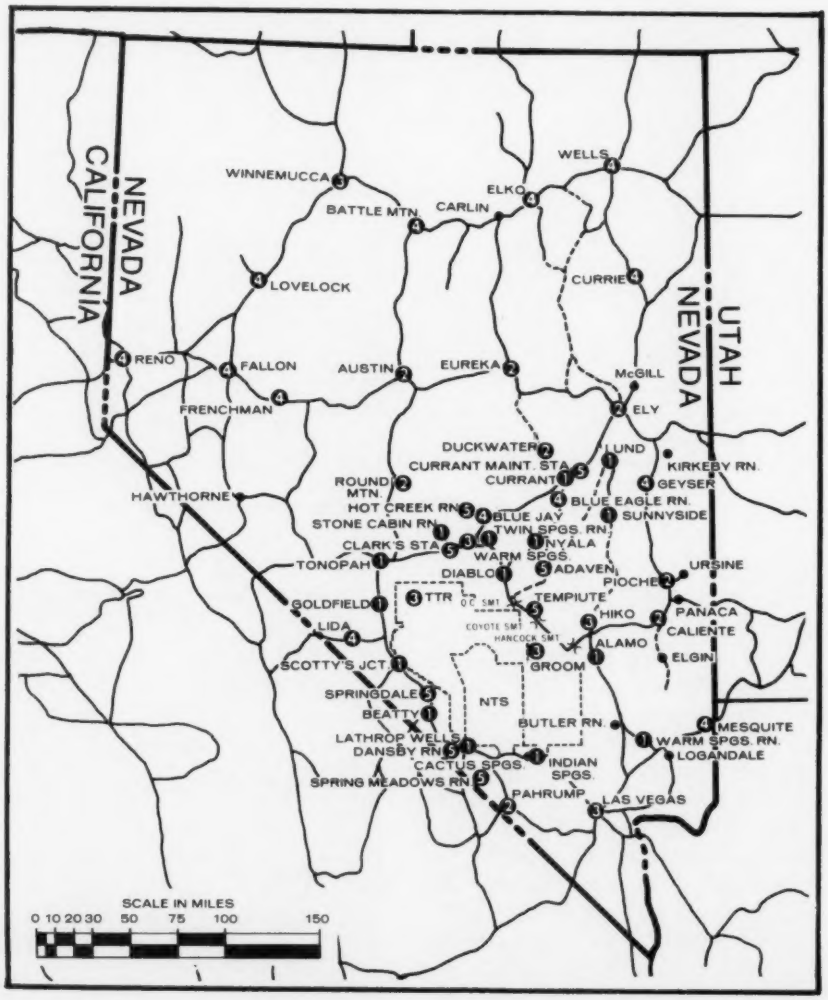

Figure 1. NERC-LV Air Surveillance Network stations in Nevada

Air Surveillance Network, December 1972

National Environmental Research Center—Las Vegas,[1] Environmental Protection Agency

The Air Surveillance Network[2] (ASN), operated by the National Environmental Research Center-Las Vegas (NERC–LV), consists of 104 active and 18 standby sampling stations located in 21 western States (figures 1 and 2). The network is operated in support of nuclear testing sponsored by the Atomic Energy Commission (AEC) at the Nevada Test Site (NTS), by the Space Nuclear Systems Office at the Nuclear Rocket Development Station (which lies within the NTS), and by the AEC at any other designated testing sites.

The stations are operated by State health department personnel and by private individuals on a contract basis. All active stations are operated continuously with filters being exchanged over periods generally ranging from 24 to 72 hours. All samples are mailed to the NERC–LV unless special retrieval is arranged at selected locations in response to known releases of radioactivity from the NTS. A complete description of sampling and analytical procedures was presented in February 1972 issue of *Radiation Data and Reports.*

[1] Formerly the Western Environmental Research Laboratory.

[2] The ASN is operated under a Memorandum of Understanding (No. AT(26–1)–539) with the Nevada Operations Office, U.S. Atomic Energy Commission.

Results

Table 1 presents the monthly average gross

Figure 2. NERC-LV Air Surveillance Network stations outside Nevada

Table 1. Summary of gross beta radioactivity concentrations in air, December 1972

Location		Number of samples	Concentration (pCi/m³)		
			Maximum	Minimum	Average *
Ariz:	Kingman	31	<0.1	<0.1	0.1
	Phoenix	30	.1	<.1	.1
	Seligman	31	<.1	<.1	.1
	Winslow	31	.1	<.1	.1
Ark:	Little Rock	10	.1	<.1	.1
Calif:	Baker	25	.2	<.1	.1
	Barstow	30	.1	<.1	.1
	Bishop	30	.1	<.1	.1
	Death Valley Junction	31	<.2	<.1	.1
	Furnace Creek	31	.1	<.1	.1
	Indio	30	.1	<.1	.1
	Lone Pine	29	.1	<.1	.1
	Needles	24	.2	<.1	.1
	Ridgecrest	31	.1	<.1	.1
	Shoshone	31	.1	<.1	.1
Colo:	Denver	19	.1	<.1	.1
	Durango	31	.1	<.1	.1
Idaho:	Boise	27	.2	<.1	.1
	Idaho Falls	21	.1	<.1	.1
	Preston	30	.2	<.1	.1
	Twin Falls	30	<.1	<.1	.1
Iowa:	Iowa City	18	.1	<.1	.1
	Sioux City	24	.1	<.1	.1
Kans:	Dodge City	31	<.1	<.1	.1
La:	Lake Charles	20	.1	<.1	.1
	Monroe	17	.1	<.1	.1
	New Orleans	18	<.1	<.1	.1
Minn:	Minneapolis	20	.1	<.1	.1
Mo:	Joplin	31	<.1	<.1	.1
	St. Joseph	31	1.0	<.1	.1
	St. Louis	30	.1	<.1	.1
Nebr:	North Platte	24	.1	<.1	.1
Nev:	Alamo	30	.1	<.1	.1
	Austin	12	<.1	<.1	.1
	Battle Mountain	30	.1	<.1	.1
	Beatty	31	.1	<.1	.1
	Blue Eagle Ranch (Currant)	30	.2	<.1	.1
	Blue Jay	31	.1	<.1	.1
	Caliente	31	.3	.1	.1
	Currant	8	<.1	<.1	.1
	Currant Ranch	32	<.6	<.1	.1
	Currie	5	<.1	<.1	.1
	Diablo	31	.2	<.1	.1
	Duckwater	29	.2	<.1	.1
	Elko	31	.1	<.1	.1
	Ely	31	<.1	<.1	.1
	Eureka	31	<.1	<.1	.1
	Fallini's Twin Springs Ranch	31	.1	<.1	.1
	Fallon	31	.1	<.1	.1
	Frenchman Station	31	.3	<.1	.1
	Geyser Maintenance Station	30	<.1	<.1	.1
	Goldfield	30	.1	<.1	.1
	Groom Lake	19	.1	<.1	.1
	Hiko	31	.1	<.1	.1
	Indian Springs	31	<.1	<.1	.1
	Las Vegas	18	.1	<.1	.1
	Lathrop Wells	29	.1	<.1	.1
	Lida	31	<.1	<.1	.1
	Lovelock	31	.1	<.1	.1
	Lund	18	<.1	<.1	.1
	Mesquite	31	.1	<.1	.1
	Nyala	31	.2	<.1	.1
	Pahrump	15	<.1	<.1	.1
	Pioche	30	<.1	<.1	.1
	Reno	31	.1	<.1	.1
	Round Mountain	31	<.5	<.1	.1
	Scotty's Junction	30	<.1	<.1	.1
	Stone Cabin Ranch	31	.1	<.1	.1
	Sunnyside	22	.1	<.1	.1
	Tonopah	31	.1	<.1	.1
	Tonopah Test Range	23	<.1	<.1	.1
	Warm Springs	31	.1	<.1	.1
	Warm Springs Ranch	31	.1	<.1	.1
	Wells	31	<.1	<.1	.1
	Winnemucca	31	.1	<.1	.1
N. Mex:	Albuquerque	19	<.4	<.1	.1
	Carlsbad	27	.2	<.1	.1
Okla:	Muskogee	29	<.1	<.1	.1
Oreg:	Burns	27	.1	<.1	.1
	Medford	23	<.1	<.1	.1
S. Dak:	Aberdeen	31	<.1	<.1	.1
	Rapid City	30	.1	<.1	.1
Tex:	Abilene	26	.2	<.1	.1
	Amarillo	31	.1	<.1	.1
	Austin	16	.1	<.1	.1
	Fort Worth	30	<.1	<.1	.1

See footnote at end of table.

Table 1. Summary of gross beta radioactivity concentrations in air, December 1972—continued

Location		Number of samples	Concentration (pCi/m³)		
			Maximum	Minimum	Average [a]
Utah:	Bryce Canyon	22	<.1	<.1	.1
	Cedar City	31	<.2	<.1	.1
	Delta	31	.2	<.1	.1
	Dugway	31	.2	<.1	.1
	Enterprise	31	<.1	<.1	.1
	Garrison	31	<.1	<.1	.1
	Logan	30	.2	<.1	.1
	Milford	30	<.2	<.1	.1
	Monticello	31	<.1	<.1	.1
	Parowan	28	.2	<.1	.1
	Provo	31	.1	<.1	.1
	Roosevelt	31	.5	<.1	.2
	Salt Lake City	30	.1	<.1	.1
	St. George	31	<.2	<.1	.1
	Wendover	9	<.1	<.1	.1
Wash:	Seattle	20	<.1	<.1	.1
	Spokane	19	.1	<.1	.1
Wyo:	Rock Springs	29	<.1	<.1	.1
	Worland	31	.2	<.1	.1

[a] Individual values less than the minimum detectable concentration (MDC) are set equal to the MDC for averaging. A monthly average less than the minimum reportable value of 0.1 pCi/m³ is reported as <0.1.

beta concentrations in air for each of the network stations. The highest gross beta concentrations within the network was 1.0 pCi/m³ at St. Joseph, Mo. The minimum reporting concentration for gross beta is 0.1 pCi/m³. For averaging purposes, individual concentrations which are below the minimum detectable concentration (0.06 pCi/m³) are assumed to be equal to the minimum detectable concentration. Averages less than the minimum reporting level (0.1 pCi/m³) are reported as <0.1 pCi/m³. No radionuclides were identified by gamma spectrometry on any filters or charcoal cartridges during December.

Complete copies of this summary and listings of the daily gross beta and gamma spectrometry results are distributed to EPA regional offices and appropriate State agencies. Additional copies of the daily results may be obtained from the NERC–LV upon written request.

SECTION IV. OTHER DATA

This section presents results from routine sampling of biological materials and other media not reported in the previous sections. Included here are such data as those obtained from human bone sampling, Alaskan surveillance, and environmental monitoring around nuclear facilities.

Environmental Levels of Radioactivity at Atomic Energy Commission Installations

The U.S. Atomic Energy Commission (AEC) receives from its contractors semiannual reports on the environmental levels of radioactivity in the vicinity of major Commission installations. The reports include data from routine monitoring programs where operations are of such a nature that plant environmental surveys are required.

Releases of radioactive materials from AEC installations are governed by radiation standards set forth by AEC's Division of Operational Safety in directives published in the "AEC Manual." [1]

A summary of the environmental radioactivity data follow for Rocky Flats Plant.

[1] Title 10, Code to Federal Regulations, Part 20, "Standards for Protection Against Radiation" contains essentially the standards published in Chapter 0524 of the AEC Manual.

1. Rocky Flats Plant [2] January–December 1970

Dow Chemical Company
Golden, Colo.

The Rocky Flats Plant (RFP) is engaged in routine production operations involving plutonium and uranium under contract to the Atomic Energy Commission (AEC). Its location, relative to population centers, is shown in figure 1. The basic goal guiding these operations is total containment of radioactive materials. The environmental survey program is designed to assure that radioactive materials released are below the AEC standards. Following a fire in a plutonium production building on May 11, 1969, environmental monitoring was enhanced, including expanded plutonium analyses of air, water, vegetation, and soil samples as well as gross alpha analyses (uranium plus plutonium) routinely performed.

[2] Summarized from "Environmental Survey, January–June, July–December 1970", The Dow Chemical Company, Rocky Flats Division, Golden, Colo.

The plant is located about 15 miles northwest of Denver, Colo. The surface stratum in this area consists of gravel washed out of the highly mineralized front range of the Rocky Mountains, where heterogeneous low-level deposits of uranium, thorium, and radium exist in the soil. These materials are measurable in most samples of air, water, and vegetation.

Air

Air samples, representative of 10 minutes of each hour, were collected at Coal Creek Canyon, Marshall, Boulder, Lafayette, Broomfield, Wagner Station, Golden, Denver, and Westminster. Samples are collected weekly and analyzed for total long-lived alpha radioactivity. The monthly average gross alpha radioactivity is shown in table 1. The recommended AEC concentration guide for insoluble plutonium is 1 pCi/m^3 averaged over 1 year for the individual in the general population. The measured activity in table 1 ranges from 2 to 29 fCi/m^3 for January to June and 1 to 9 fCi/m^3 for July to December and is indistinguishable from

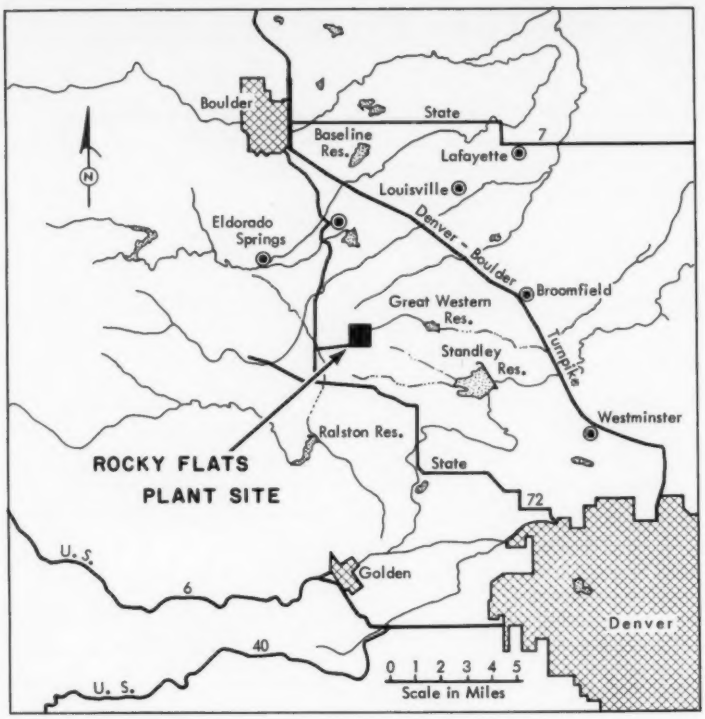

Figure 1. Location of Rocky Flats Plant

Table 1. Gross long-lived alpha (uranium + plutonium) in offsite air samples. RFP environs, January–December 1970

Location	Average concentration (fCi/m³)					
	January	February	March	April	May	June
Boulder	8	11	10	10	9	8
Broomfield	4	9	9	14	7	6
Coal Creek	8	9	11	9	5	6
Denver	10	9	11	9	6	9
Golden	11	15	13	16	6	9
Lafayette	9	11	11	13	11	6
Marshall	12	9	12	23	23	5
Wagner Station	5	3	4	10	7	7
Westminster	9	11	16	29	6	2

	July	August	September	October	November	December
Boulder	6.0	7.1	7.9	5.8	4.9	4.9
Broomfield	5.6	7.3	6.0	6.0	4.1	2.7
Coal Creek	5.6	5.1	4.3	4.3	4.7	3.1
Denver	5.1	5.4	4.7	4.7	4.5	3.9
Golden	6.0	5.6	5.1	6.0	4.1	5.5
Lafayette	6.0	5.8	8.1	4.7	4.7	5.7
Marshall	5.6	8.6	5.6	5.5	4.8	4.6
Wagner Station	4.7	5.1	5.6	6.4	5.0	1.1
Westminster	4.9	5.4	4.9	6.0	5.5	5.6

levels of activity resulting from naturally-occurring long-lived alpha emitters. The fluctuations in the range are statistical variations due to the low levels of activity being measured.

Water

Four reservoirs in the area are sampled biweekly. Local community tap water samples are collected monthly. A small pond on Walnut Creek at Indiana Street (Rocky Flats effluent course) is sampled weekly. Other streams and lakes in the area are sampled twice a year. These samples are analyzed for gross alpha radioactivity content (uranium plus plutonium) and for plutonium by alpha spectrometry. Tables 2 and 3 summarize the results of the water sampling program. For January–June 1970 the results indicate a gross alpha range of <0.1 to 11 pCi/liter in the reservoirs and Walnut Creek sampling program and <0.1 to 13 pCi/liter from the community tap water supplies. The radioactivity of the Ralston Reservoir samples (11 pCi/liter) and the Arvada tap water sample (13 pCi/liter) has been identified in both cases as >99 percent uranium. The AEC guide for natural uranium is 20,000 pCi/liter. Maximum plutonium concentration noted was

Table 2. Radioactivity in reservoir samples, RFP environs, January–December 1970

Reservoir	Number of samples	Gross alpha radioactivity (plutonium + uranium) (pCi/liter)		Number of samples	Plutonium radioactivity (pCi/liter)	
		Range	Average		Range	Average
January–June 1970						
Baseline	10	<0.1– 0.5	<0.2	6	<0.02–0.14	<0.05
Great Western	11	.1– .8	.2	8	<.02– .23	<.10
Ralston	11	.8–11	3.1	8	<.02– .80	<.17
Standley	9	.1– .6	.4	8	<.02– .10	<.07
Walnut Creek	19	.2– 4.5	1.7	16	<.02–1.45	<.62
July–December 1970						
Baseline	13	0.18 – 9.00	2.77	9	<0.004 –1.53	<0.14
Great Western	13	.13 –9.40	1.96	9	<.004 – .43	<.08
Ralston	13	.50 –65.0	19.1	8	<.004 – .06	<.02
Standley	13	.80 –10.10	3.7	9	<.004 – .21	<.08
Walnut Creek	26	<.005–40.19	<5.49	22	<.0004–5.64	<.75

Table 3. Radioactivity in community tap water, RFP environs, January–December 1970

Station	Number of samples	Gross alpha radioactivity (plutonium + uranium) (pCi/liter)		Number of samples	Plutonium radioactivity (pCi/liter)	
		Range	Average		Range	Averge
January–June 1970						
Arvada	10	0.5–12.7	2.86	7	<0.02–0.36	<0.11
Boulder	10	<.1– .6	<.2	7	<.02– .06	<.03
Broomfield	8	<.1– .6	<.2	4	<.02– .10	<.06
Denver	9	.1– 2.0	1.2	8	<.02– .29	<.10
Golden	10	<.1– .7	<.4	7	<.02– .12	<.07
Lafayette	9	<.1– 3.5	<.5	5	<.02– .91	<.22
Louisville	9	<.1– 1.4	<.4	7	<.02– .32	<.10
Thornton	10	.2– 3.9	1.7	8	<.02– .16	<.06
Westminster	9	<.1– .7	<.2	5	<.02– .11	<.05
July–December 1970						
Avada	13	0.09 –17.65	3.23	10	<0.0004–0.62	<0.12
Boulder	13	<.005–11.28	<1.39	2	<.0004– .06	<.03
Broomfield	13	<.005– 4.57	<2.36	9	<.0004– .58	<.08
Denver	13	<.005–17.78	<3.65	10	<.0004– .16	<.04
Golden	13	.07 – 7.11	2.09	6	<.0004– .21	<.06
Lafayette	13	.05 –10.27	2.13	5	<.0004– .59	<.22
Louisville	13	<.005–13.72	<1.61	4	<.0004– .19	<.07
Thornton	13	.42 – 7.38	3.01	11	<.0004–1.64	<.21
Westminster	13	<.005– 3.46	<.76	5	<.0004– .07	<.02

1.45 pCi/liter in a sample taken from Walnut Creek at Indiana Street.

The July–December 1970 results indicate a gross alpha concentration range of <0.005 to 65 pCi/liter in the reservoirs and <0.005 to 18 pCi/liter for the community tap water supplies. The 65 pCi/liter activity in Ralston Reservoir and the 18 pCi/liter level in the Denver tapwater were identified as natural uranium. Maximum plutonium concentration noted was 5.64 pCi/liter in a sample taken from Walnut Creek at Indiana Street.

Fallout

Fallout collection trays are located at all offsite air sampling stations and at standby stations located in Arvada, Eastlake and Superior and analyzed for plutonium. More recently, fallout samples from Berthoud and Castle Rock, Colo. also have been collected and analyzed for plutonium. The reported values include fallout resulting from atmospheric atomic test programs as well as that originating from operations at Rocky Flats. Table 4 summarizes the measurements for the January–December 1970 period.

Table 4. Plutonium radioactivity in fallout, RFP environs, January–December 1970

Location	Number of days measured	Average plutonium radioactivity (pCi/m²-month)[a]
January-June 1970		
Arvada	154	5.00
Boulder	127	6.59
Broomfield	154	4.98
Coal Creek	95	5.93
Denver	154	5.88
Eastlake	143	4.27
Golden	154	4.11
Lafayette	154	4.93
Marshall	140	8.24
Superior	154	3.69
Wagner Station	154	10.0
Westminster	126	7.63
July–December 1970		
Arvada	167	9.20
Berthoud	97	<.50
Boulder	153	29.94
Broomfield	153	21.08
Castle Rock	100	<.50
Coal Creek	154	6.75
Denver	181	5.99
Eastlake	153	8.94
Golden	167	19.83
Lafayette	167	3.33
Marshall	167	6.14
Superior	181	9.84
Wagner Station	178	15.02
Westminster	146	10.58

[a] This includes worldwide fallout.

Vegetation

Vegetation samples have been collected semiannually. These samples are analyzed for gross alpha content only. Samples collected from 63 locations during the July–December period were analyzed with activity levels ranging from <0.003 to 0.670 pCi/g dry weight. These results are comparable in activity levels to previous environmental surveys conducted at Rocky Flats. Results for July–December 1970 are summarized in table 5.

Table 5. Gross alpha radioactivity in vegetation samples RFP environs, July–December 1970

Distance from plant	Number of samples	Gross alpha radioactivity (pCi/g dry weight)	
		Range	Average
<5 miles	42	0.003–0.666	0.096
>5 miles	21	.003– .526	.106

Soil

Twenty-three offsite soil samples have been analyzed for plutonium during January–June 1970. These were taken from unsampled locations 2 to 5 miles from the plant. These results are compared with 1969 results in table 6 and show no differences.

Table 6. Plutonium content of offsite soil samples 1969, 1970

Date	Distance from plant	Number of samples	Radioactivity (dpm/g)	
			Range	Average
1969	5 miles or less	48	[a] 0.4–6.7	1.4
1970	2 to 5 miles	23	[b] .1–6.7	1.4

[a] Rocky Flats Lake road at South Boulder Diversion Canal.
[b] Highway 93, ¼-mile south of plant access road.

Table 7 summarizes strontium-90 and plutonium concentrations made on 1969 soil samples. Comparison of plutonium to strontium-90 ratios at various locations might afford an interpolation of the origin of the plutonium in the soil; however, the wide range of strontium-90 concentrations found make any ratio comparison meaningless. No subsequent strontium-90 analyses are planned.

In the July–December period, soil samples were collected within a radius of approximately

Table 7. Plutonium to strontium-90 ratios in soil samples (1969 collection)

Number of samples	Distance from plant	Disintegrations/minute/gram			Plutonium to strontium-90 ratio
		Radioactivity (dpm/g)	Plutonium	Strontium-90	
10	1 mile	Average	1.9	3.55	0.54
		Range	1.2–3.9	0.25–15.9	0.02–11.0
19	2 miles	Average	1.5	3.06	.49
		Range	.2–6.7	.04–30.9	.02–22.3
16	5 miles	Average	1.0	13.2	.08
		Range	.5–3.3	.17–60.0	.01– 6.5

20 miles from the Rocky Flats Plant and were analyzed for plutonium. Samples collected during this period are awaiting analysis.

Recent coverage in *Radiation Data and Reports:*

Period	Issue
January–December 1969	October 1972

Reported Nuclear Detonations, March 1973

(Includes seismic signals presumably from foreign nuclear detonations)

The U.S. Atomic Energy Commission conducted an underground nuclear test at its Nevada Test Site on March 8, 1973. The test was in the low-intermediate yield range of 20 to 200 kilotons.

Not all of the nuclear detonations in the United States are announced immediately, therefore, the information in this section may not be complete. A complete list of announced U.S. nuclear detonations may be obtained upon request from the Division of Public Information, U.S. Atomic Energy Commission, Washington, D.C. 20545.

★U.S. GOVERNMENT PRINTING OFFICE: 1973 — 514-847/9

SYNOPSES

Synopses of reports, incorporating a list of key words, are furnished below in reference card format for the convenience of readers who may wish to clip them for their files.

RADIOBIOASSAY PROGRAM OF THE INSTITUTIONAL TOTAL DIET SAMPLING NETWORK II. SELECTED PHYSIOLOGICAL CONSTANTS OF URINE. *A. A. Moghissi* and *Mary G. Mayes. Radiation Data and Reports*, Vol. 14, April 1973, pp. 225–232.

The Institutional Total Diet Sampling Network program, initiated in 1961, has provided information on the intake of certain radionuclides by selected groups of children and young adults, and the resulting radiation dose. Starting with 1966, this was supplemented by a radiobioassay program with the aim of improving radiation dose estimates by using escretion data. Numerous physiological parameters were measured to evaluate their suitability for the validation of a 24-hour urine sample.

The results of measurements of volume, specific gravity, pH value, osmolality, and creatinine in samples collected during 1966–1968 are summarized. Results of these measurements, along with a review of available data, with particular emphasis on creatinine, are presented and discussed.

KEYWORDS: Body burden, children, creatinine, diet, excretion, radiobioassay.

RADIOBIOASSAY PROGRAM OF THE INSTITUTIONAL TOTAL DIET SAMPLING NETWORK III. CESIUM-137 DOSE ESTIMATES AND BODY BURDENS OF CHILDREN. *A. A. Moghissi* and *Mary G. Mayes. Radiation Data and Reports*, Vol. 14, April 1973, pp. 233–236.

Urine samples collected from 10 stations of the Institutional Total Diet Sampling Network program were analyzed. Cesium-137 and potassium in food and urine were analyzed by gamma spectroscopy. The cesium-137 body burdens were established by using content of urine and the biological half-life of cesium in children, and by a model based on intake.

Differences among results obtained, using each of these techniques, are discussed. Radiation dose calculations are based on recommendations in International Commission on Radiation Protection Report Number 2.

KEYWORDS: Body burdens, cesium-137, children, diet, excretion, potassium, radiobioassay.

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April 1973

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